WATTLE We Eat for Dinner

Proceedings of the Wattle We Eat for Dinner Workshop on Australian Acacias for Food Security.

Alice Springs, Australia, 16–18 August 2011

Edited by Rob Francis

Australian Government
AusAID

World Vision

Workshop goals

- To address issues of poverty, food security, environmental degradation and adaptation to climate change through the development of appropriate edible acacia production, processing and marketing systems.
- To formulate a community engagement strategy to educate and involve the Australian community in the development of edible seeded acacias.
- To create awareness and support for the current state of knowledge on edible acacias, identify gaps and kick start increased research and development action – bring people together who are working on the related acacia fields (food, marketing, taxonomy/silviculture) to share their knowledge and get to know what each other is doing.

Acknowledgements

We would like to thank those who came together to hold the first workshop on Australian acacias for food security, *Australian Dry-zone Acacias for Human Food*, at Glen Helen, Northern Territory, 20 years ago. It was those people who initiated this movement.

Thank you to the Aboriginal people of the Northern Territory who so willingly have supported the idea of Australian wattle seed helping fight malnutrition in developing countries, and whose knowledge of edible acacia seed has been built up over thousands of years and formed the basis of this initiative.

This workshop has been supported by the Australian Government's Agency for International Development (AusAID) through the Australian Non-Government Cooperation Program's Community Engagement initiative.

To Chris Harwood, Bruce Maslin and Jock Morse, who attended both workshops twenty years apart, thank you for your enthusiasm and for keeping the flame alight. And to Tony Rinaudo, Peter Cunningham and others who have guided the planting, growing and use of Australian acacias in Sahelian Africa for 30 years, and who have demonstrated how beneficial they can be in alleviating famine, as a harvestable timber product, and in improving incomes for the poor in the developing world.

The workshop wouldn't have been possible without the diligence and enthusiasm of Amanda Peters, who volunteered two days a week throughout the organisational period and then at the workshop itself. And Josie Sullivan, Community Projects Assistant at World Vision Australia, who supported the workshop's organisation in many ways and at crucial times.

Thank you to the World Vision Australia's video and photography crew, Mike Amos, Bradley Phillips and Andrew Wadey, who were responsible for recording the workshop. Thank you too, to the Chifley Alice Springs Resort and the Alice Springs Desert Park.

And finally, to the 28 experts who came from around the world to attend, participate and give their time so graciously and enthusiastically to reignite this important movement – thank you.

Rob Francis, Co-convenor and Editor

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Summary of workshop conclusions

Day 1 of the workshop was devoted to presentations (for details see Proceedings and Invited papers on page 8) and an excursion to the Alice Springs Desert Park where Bruce Maslin, Jock Morse, Wayne O'Sullivan and Peter Yates guided participants through the many species of acacia native to the Alice Springs area.

Day 2 of the workshop concentrated on three focus groups – Nutrition, Agronomy and Community Engagement. Participants were asked to brainstorm and discuss four major questions for their respective fields of expertise: What remains to be done? How will it be done? Who and when? How will it be funded?

A summary of these recommendations follows with the goal that they be collated into a five-year plan and funding proposal overseen and coordinated by Tony Rinaudo and others as required.

Nutrition

The Nutrition Focus Group chose a theme of "Enhance the nutritional status of communities through the incorporation of edible acacia into local diets" and made the following resolutions:

- Near term – to write a research proposal, with the major outcome of establishing recipes for safe and palatable foods containing processed acacia flour, based on cereals (foods) that are locally produced and consumed in the relevant individual communities in Niger and Ethiopia.
- Longer-term – to develop an acacia-based weaning food for the most vulnerable in both countries.

The group also discussed:

- screening different acacias to determine best species for food consumption.
- developing best practices for processing selected acacia species to limit anti-nutritional properties in target areas eg: Niger and Ethiopia.

Agronomy

The Agronomy Focus Group was given the task of identifying new directions for agronomic research and development of Australian acacias and to develop a five-year plan. It identified the following priorities:

- Risk management plan for *A. saligna* and other acacia species to address potential invasiveness, including (a) a cost/benefit approach and (b) monitoring built into new planting and introductions.
- Four main areas of research for *A. saligna* are proposed
  - in Ethiopia and Chile
  - assemble and review literature
  - identify existing landraces and subspecies and assess adequacy of material in Ethiopia and Chile
  - production systems for different products including methodology for multi-purpose or specific uses, site and community specific requirements, and silvicultural trials

- Exchange visits between Ethiopia and Chile
- Four main projects on acacias for Sahelian and arid/semi-arid tropics are proposed:
  - assessment of existing species in use in the Sahel (*A. colei, A. torulosa, A. tumida*)
  - research other potential species/germplasm and previous candidates in light of climate change
  - rhizobium inoculants
  - market process – strategies and practice for seed to food

Community Engagement

The Community Engagement Focus Group identified that no clear long-term communications strategy or plan existed to engage the Australian community.

The group made five key recommendations to facilitate community engagement, communications and marketing of the initiative:

1. Develop a long-term, sustained communications plan to engage the Australian community. There is an urgent need to engage Australians about the wattle story in Africa. Our goal is to raise awareness and attract "buy-in, involvement and donor support". It will be built on pride and the concept of giving a hand-up, not a hand-out in African countries.
2. The "wattle project and work" needs to be named and branded.
3. Develop a communications plan according to and in close association with the agronomy and nutrition groups' needs. It must also build on what has already been achieved.
4. More needs to be done to engage African communities. (It was noted this may fall outside the scope of this work. For further consideration.)

The group outlined a preliminary schedule and budget for the above recommendations, but this needs further consideration.

For details of the above recommendations see Recommendations of the Focus Groups *page 130*.

Proceedings and invited papers

Welcome: Wattle We Eat for Dinner Workshop

Rob Francis
Community Projects Manager
World Vision Australia

Welcome to the Wattle We Eat for Dinner Workshop. Thank you for coming. You have come from so far and wide to give your time. There is no other word to describe it other than “fantastic”. You’ve come from Nigeria, Niger, Ethiopia, Kenya, Chile, Western Australia, Tasmania, New South Wales, Victoria and the Northern Territory. It’s also marvellous to have the pre-eminent experts in this field of acacias for food security all in the one room, and all caring about trying to help people who are in need and improving their lives.

I want to introduce Tony Rinaudo. Tony is a hero to many people in developing countries, as he is to me, too. He was recently made a chief for his work in Ghana – Chief From-Little-Bushes-Big-Trees-Grow – and is also known as “Mr Tony” and embraced wherever he goes in Africa. Tony has been with this project for more than 30 years, although we will hear from a couple of people tomorrow morning who have been involved for even longer! I want to welcome Tony to give the keynote speech tonight.

Keynote speech

Tony Rinaudo
Natural Resources Research and Development Advisor
World Vision Australia

Tony Rinaudo is the Natural Resources Research and Development Advisor at World Vision Australia. Tony has a Bachelor of Rural Science and a Bible and Missions Certificate, and spent 18 years in the Niger Republic with the organisation "Serving in Mission". From 1981 to 1999, Tony managed the Maradi Integrated Development Project, and introduced Farmer Managed Natural Regeneration and Australian acacias into Nigerian farming systems. Since 1999, Tony has worked with World Vision Australia in various roles, beginning his current role in 2008.

I want to thank you all for coming to this workshop –"Australian Acacias for Food Security – reigniting research and community support". It is so good to see so many people I've worked with over the years on acacia issues, others I've only known by email and others still that I didn't know about, but who are working in their own areas of expertise.

My own involvement with acacias started over 30 years ago when I took my young family to Niger Republic, West Africa, though, growing up in Australia, I believe acacias started casting their spell on me from childhood.

When we arrived in Niger as new agricultural graduates we were very idealistic, but we had no idea of what we were getting ourselves into or what practical help we would be.

What I saw shocked me. Almost total deforestation followed by desertification, strong winds of up to 70kph causing massive soil erosion on the treeless farms, soil surface temperatures of 50°C plus, a battalion of different insect and disease problems attacking crops, severe fodder shortages, and very little firewood for the average household (most used manure and/or straw). Consequently crop yields were low in any year and totally inadequate in bad years, poverty was severe and hunger common.

For the first three years we seemed to be holding our breath during the rainy season, wondering if there would be follow-up rains and if people would have food. Farming as a way of life was so precarious - it all depended on a single, annual crop, millet, growing in a climate biased against it. The chances of failure were much, much greater than the chances of success, and in that farmers had no plan B (other than pleading to relatives and friends, and exodus to other countries), failure was disastrous.

In 1984 the inevitable happened. Severe drought in combination with grain import restrictions from Nigeria resulted in famine. I saw normally dignified old Hausa men on their haunches picking individual grains of sorghum from the sand and putting them straight into their mouth uncooked; men abandon wives and children for months on end; whole communities abandoning their villages, walking up to 100 kms to larger centres in search of food and help. I met a blind man who had walked about 70 kms for help. I drove him back home with a bag of grain. What I saw in his village was surreal. Environmental destruction had created a bare, windswept moonscape. Families were clinging to all they knew and owned hoping against hope that it would rain. If it would only rain, it would strengthen their will power to stay on a little longer and hopefully see the crop through till harvest time.

Individuals were in the fields hoeing, but really they were just going through the motions as there was no crop and no weeds. Seemingly doing something, no matter how useless, was better than doing nothing. And I saw and heard much worse than this.

Amazingly, considering the obstacles against us, we were able to help around 50,000 people with about 1800 tons of grain during the worst of the famine. At the end of 1984, I was relieved that we were able to help, but quite disturbed that the same thing could be repeated any year - if not due to drought, due to any number of issues which plagued Niger (strong winds, too much rain, insect pests …) and so I started to look for viable alternatives to millet, not necessarily to replace the millet, but to be there as a reliable back-up for the years in which millet failed. Most species that we tried didn't survive. Niger is a very tough place to try and grow things in.

In 1985, back in Australia I was notified of a CSIRO-hosted conference on acacias. Knowing very little about acacias but being interested in forestry I decided to go. Most of the presentations were on subjects that didn't really interest me – acacias for tanning leather, for paper pulp, for electricity generation, for commercial lumber … However, one speaker talked about the nutritional value of certain acacia species, and as they say, the rest is history.

With seed and technical assistance from CSIRO, acacia species trials were conducted in Niger. Many people in CSIRO helped but in particular I want to single out Dr. Chris Harwood for putting acacias on CSIRO's radar and for his personal sacrifice above and beyond the call of duty to move this work forward. Great progress was made in the fields of species selection and understanding the safety and nutritional value of the acacias because of Chris' work.

If you were a modern plant breeder with all the gene technology you needed in one hand and a jar full of genes in another, you would be hard pressed to design a plant with a more desirable combination of traits for Niger's conditions in one plant:

- drought tolerance – does not need watering if planted after good rain
- thrives in high temperatures
- good seed production (0.5 – 6 kg seed/tree in second year) and ease of harvest
- nutritious seed (40% CHO, 25% protein, 6% fats)
- long storage life of seed
- seed is very tasty and flexible in terms of recipes it can be used in
- high biomass production (rapid growth) (i.e. firewood and leaf litter for mulch and organic matter)
- nitrogen fixing
- good windbreak features
- withstands heavy pruning
- leaves not attractive to goats or livestock

In short, acacias showed enormous untapped potential and in light of the recurring famines there, seemed to be a perfect match.

During and following the species trials, acacia planting and training on how to utilize the seed was included in food-for-work programs during famine time. In this way, a whole district became familiar with the plants and learned about their food value.

CSIRO engaged a nutritionist, Dr. Steve Adewusi, to check the seed of *A. colei* and *A. tumida* for safety through chemical tests, animal experiments and finally a human volunteer trial. We promoted acacias in around 100 villages and people seemed to be excited about them, but there was never any lasting uptake except in just a handful of villages.

Peter Yates began buying seed from our Nigerien farmers in around 2003–04 with the dream of creating a fair trade product which would funnel development funds back into the communities. This failed miserably as a fair trade scheme but, significantly, it seemed to greatly stimulate interest in eating acacias locally.

At that time, Peter Cunningham co-managed a development project which walked alongside farmers, coaching them to plant and care for acacias and teaching women how to cook them. He also developed the farmer-managed agroforestry farming system which builds on a foundation of natural regeneration of existing indigenous trees and adds acacias, mulching or crop residues and annual crop rotation to the mix.

Despite all this, there still hasn't been the spontaneous uptake of acacias in farming systems or in local diets that we hoped for. Yet, the need is no less today than it was in 1984. In Niger alone the population has risen from 9 million in the 1990s to 15 million today, land degradation continues to erode yields and increasingly, climate change seems to wreak havoc on annual crops. The current crisis in East Africa gives a stark reminder that the need for solutions is greater today than ever before. In 2010, Roland Bunch did a study in six African nations (Zambia, Malawi, Kenya, Uganda, Niger and Mali). He wrote about his findings in the 2011 *State of the World Report* and titled the chapter 'The Coming Famine'. He concluded that four major factors are coming together all at once in a sort of "perfect storm" that will almost surely result in an African famine of unprecedented proportions, probably within the next four to five years. It will most heavily affect the lowland, semi-arid to sub-humid areas of Africa (including the Sahel, parts of eastern Africa, plus a band from Malawi across to Angola and Namibia), and he calculated that unless the world does something dramatic, 10 to 30 million people could die from famine between 2015 and 2020.

In addition to the need, another reason for continuing this research and development is that I don't believe we came so far for nothing. We are too close to seeing a breakthrough to give up now. A little over a year ago I was thinking about all the progress that had been made in developing and promoting acacias, the various promotion approaches that had been used and I was keenly feeling the disappointment of seeing so much unrealised potential.

I wondered to myself – where to from here? What is the next step? As I glanced across my bookshelf the proceedings from the first acacia workshop caught my eye. I started looking up the recommendations to see if I'd missed anything. Before long I realized that August 2011 would mark 20 years since the first workshop. Then I had the answer to my question. The next step is to bring everybody together and give them a chance to know each other and what the other is doing, find out what the state of knowledge is, identify the gaps, and forge a path, not for the next 20 years, but for the next five years.

And so, here we are, and this is what we are setting out to do:

- To address issues of poverty, food security, environmental degradation and adaptation to climate change through the development of appropriate edible acacia production, processing and marketing systems.
- To create awareness and support for the current state of knowledge on edible acacias, identify gaps and kick-start increased research and development action.
- To bring people together who are working on the related acacia fields (food, marketing, taxonomy/silviculture) to share their knowledge and get to know what each other is doing.
- To activate people and financial resources for the development of edible-seeded acacias.

So I hope that you all have a very enjoyable and productive time, that you will strengthen old friendships and make new ones that will advance the utilisation of acacias.

I apologise in advance that the time given to speakers is all too short. There are also some here who should be sharing about their work to the whole group but there just isn't time in the program. However, I believe the value from this workshop will come out of the small groups. So I urge you to share with others what you are working on in those sessions and that you make strategic alliances and continue your discussions after the workshop.

Finally, I want to thank AusAID for their faith in the importance of this topic and for funding this workshop. Special thanks go to Rob Francis and his helpers Josie Sullivan and Amanda Peters for organizing it. It simply wouldn't have happened without Rob's skill, hard work and dedication. And I thank you all in advance for the contribution you will make, for the commitment you've shown in dropping what you are doing and coming here.

I really hope you have an enjoyable and productive time, may you strengthen old friendships, may you build new ones and advance the research, development and utilisation of acacias for the benefit of the world's poor and hungry.

Australian acacia seeds for human food in developing countries: Looking back and looking forward

Chris Harwood
Senior Principal Research Scientist
CSIRO Ecosystems Sciences

Chris Harwood is a Senior Principal Research Scientist with CSIRO Ecosystems Sciences. Since 1988, he has worked for CSIRO on the genetic resources, genetic improvement, plantation development and utilisation of Australian tree species. He has authored/co-authored over 60 peer-reviewed scientific papers and five books, has led major development assistance projects in Asian and African countries and has extensive experience in training and capacity building for forest science.

The presentation commences with Chris Harwood's opening remarks to the workshop, followed by his paper on the subject.

It was 20 years ago today …

It's indeed a great pleasure and honour to give an important talk in this workshop. It's good to see some old friends and new faces too. I am hoping to see acacia really go places in the next 20 years. As Tony mentioned, we had a workshop almost 20 years ago and it was bitterly cold; now it's very pleasant weather. After that workshop myself and Alan House brought out the proceedings and they were pretty widely distributed. The first thing I would like to do is acknowledge that the basic idea of using these Australian trees in developing countries came from the knowledge of Aboriginal people in Australia – the species they used and the ways they used them. The traditional owners who attended the first workshop were very generous and said they were happy to see this knowledge become available worldwide to assist with food security. As you can see in the photographs, we had some of the Aboriginal ladies demonstrating their preparation methods. In 1987 I was very privileged to travel to Niger with two Aboriginal ladies. We visited the people in Miradi who were adopting acacia as a food source.

Abstract

The 1991 meeting Australian 'Dry Zone Acacias for Human Food', held at Glen Helen, assembled scientific information and developed a plan for coordinated research to underpin the development of Australian acacia seeds as a significant food in developing countries,

specifically the semi-arid Sahelian region of Africa. Most of the proposed research program was in fact carried out, and scientific reports were published, within ten years of the conference. It is interesting to reflect on why, despite two decades of promotion, there has not been widespread spontaneous adoption of Australian acacia seeds as a major new food source in the target region.

While the technical feasibility of producing significant quantities of edible and nutritious seeds from the target species in Sahelian countries has been established, it seems that farmers have not yet perceived a clear net benefit from incorporating these acacia species into their farming systems. Agronomic trials suggest that yields of seed are relatively modest (unlikely to exceed 50–100 kg per hectare per year in farming systems). Unless a commercial demand for acacia seeds can be developed, it seems unlikely that Australian acacia species will be adopted as a major food source in the Sahel. Future agronomic research should be participatory, largely driven by potential farmer-adopters, and should focus on the farm-level economics (inputs, compared to outputs of seed, wood and other benefits) of growing acacias in Sahelian farming systems.

Prospects for seeds of *Acacia saligna* making a significant contribution to food security in northern Ethiopia may be good, because extensive *A. saligna* plantings, established for other purposes, are producing seed crops which could be exploited for food. Demand for seed therefore does not have to drive tree cultivation. Research in Ethiopia might best focus on nutritional/toxicological evaluation, seed yields and seed collection/extraction systems and incorporation of seeds into local foods and diets, while the potential weediness of this species must be kept under review. A participatory research approach, conducted with likely adopters and participants in the food supply chain, is suggested.

Looking back to 1991

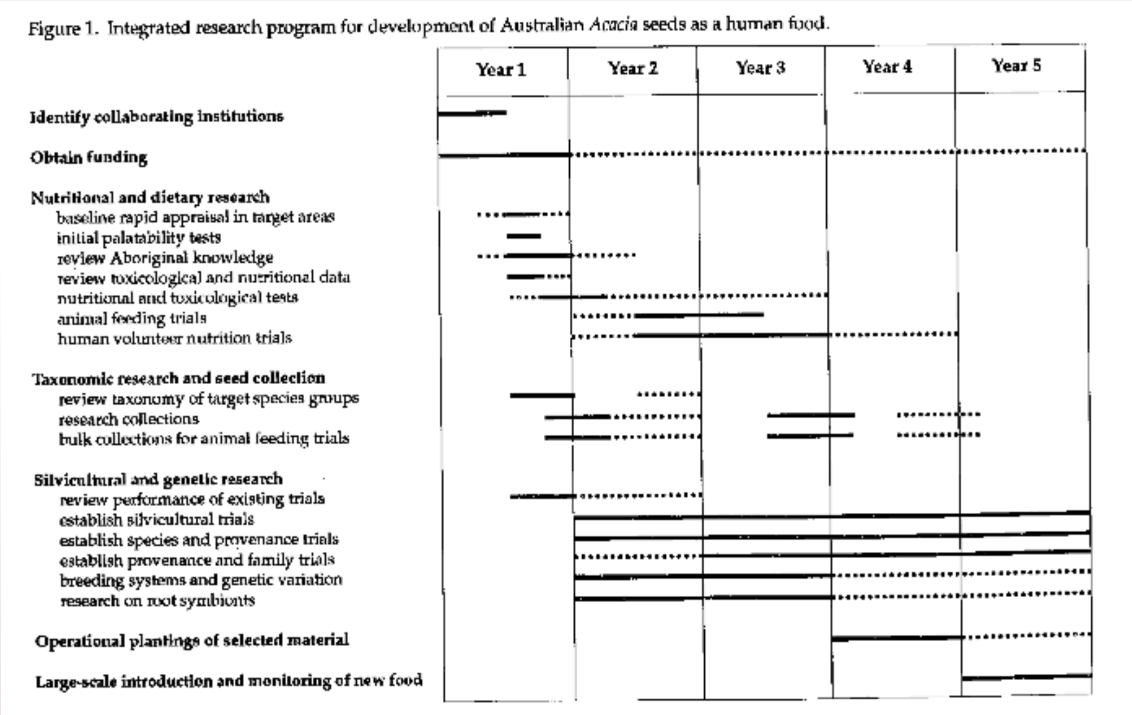
It is fascinating to review the Glen Helen workshop proceedings, written nearly 20 years ago (House and Harwood 1992).

The first introductions of Australian acacia species to the African Sahel in the 1980s are summarised by Souvannavong and De Framond (1992) in the Glen Helen workshop proceedings. Trials evaluated species and provenance performance primarily for fuelwood production, focussing on growth and survival in conventional “forestry” block planting arrangements. This work established that several species, notably *A. colei*, displayed outstandingly rapid early growth to age 3–4 years in the semi-arid tropical climates (mean annual rainfall 500 –700 mm) and sandy soils of several Sahelian countries.

Tony Rinaudo, then working with the Maradi Integrated Development Project (MIDP), was motivated by his knowledge of traditional Aboriginal consumption and the observation of heavy seed crops on *A. colei* growing around Maradi, Niger to evaluate the food potential of Australian acacia seeds for the Sahel. Follow-up visits to Maradi by CSIRO scientists Lex Thomson and discussions with Lex and Chris Harwood led to CSIRO organising the first Glen Helen workshop in 1991.

Figure 1 shows the “action plan” which summarises the research program that was proposed to underpin development of acacia seeds as a human food.

Figure 1: Glen Helen research and development plan (House and Harwood 1992)



Let's compare this with what actually happened. Figure 2 is my interpretation of what has been achieved over the last 20 years, as elaborated in the following sections. Most of the proposed integrated research program was in fact carried out, and scientific reports were

Figure 2: Summary of research and development on edible acacia seeds carried out subsequent to Glen Helen workshop

	1992	1995	2000	2005	2010
Identify collaborating institutions					
Obtain funding	yes	yes	yes		
Nutritional and dietary research					
baseline rapid appraisal in target areas	yes	yes			
initial palatability review	yes				
review Aboriginal knowledge	yes	yes			
review toxicological and nutritional data	yes				
nutritional and toxicological tests	yes	yes			
animal feeding trials	yes	yes	yes		
human volunteer nutrition trials		yes			
Taxonomic research and seed collection					
review taxonomy of target groups	yes	yes	yes		
research collections	yes	yes	yes		
bulk collections for animal feeding trials	yes				
Silvicultural and genetic research					
review performance of existing trials	yes				
establish silvicultural trials		yes	yes	yes	
establish species and provenance trials		yes	yes	yes	
breeding system and genetic variation		yes			
research on root symbionts				yes	yes
Operational plantings of selected material					no
Large scale introduction and monitoring of new food					no

published and made available to development agencies, within ten years of the conference (Harwood et al. 1999). It is interesting to reflect on why, despite two decades of promotion, there has not been widespread spontaneous adoption of Australian acacia seeds as a major new food source in the Sahelian target region.

Nutrition and dietary research

A large body of research on nutritional value and toxicology of acacia seed flour, mostly *A. colei* and *A. tumida*, was carried out during the 1990s, most of it by Dr Steve Adewusi's group at Obafemi Awolowo University, Nigeria. Financial support was provided by ACIAR. Steve has ably summarised the results of these studies and their implications for our current workshop, citing seven refereed journal papers arising from his work. Broadly speaking, this research has established that these species are not dissimilar to other edible legume seeds in their food value, and could make a useful contribution to both Sahelian and Western diets. While there are no major toxicological concerns, acacia seed flour is not a complete food, and should be eaten as part of a balanced diet where it can complement other food types. The three-week human volunteer feeding trial that Steve conducted at Maradi, Niger, in 1995 demonstrated that Sahelian men and women could enjoy and thrive on a diet that incorporated up to 25% *A. colei* acacia seed flour by weight. However, work remains to be done to ensure that potentially vulnerable groups (pregnant women, infants and people with challenged immune systems) can safely consume a high proportion of acacia-incorporated foods on a regular basis. The modified amino acid S-carboxythlcysteine, CEC), which contributes to the non-protein nitrogen in *A. colei* seeds, competes with methionine, reducing the nutritional value of the seed, and raising the prospect of screening for low CEC varieties with better nutritional characteristics.

Silvicultural trials in Niger (Cunningham et al. 2008) have subsequently confirmed *A. torulosa* as another candidate species for the Sahel, but this species has yet to receive detailed nutritional evalutation. Similarly, *A. saligna* has recently emerged as a prospective food source in northern Ethiopia but its seeds have been little studied as a food, although it is known that they were consumed by Australian Aboriginal people.

Taxonomic research and seed collection

During the 1990s, Australian botanists Bruce Maslin, Maurice McDonald and Lex Thomson revised the taxonomy of the most promising species groups of Australian acacias, notably the *Acacia holosericea/A. colei* group (Maslin and Thomson 1992). *A. cowleana* and *A. elachantha* (McDonald and Maslin 1997b), *A. thomsonii* (Maslin and McDonald 1996) and *A. tumida* and its relatives (McDonald 2003). This led to description of several new acacia species and subspecies. More recently, Western Australian researchers (George et al. 2006, Maslin and McDonald in prep.) intensively evaluated the genetic resources of *A. saligna*, because of the interest in growing this species on a large scale in the Western Australian wheat belt for hydrological control and products such as animal fodder and biomass for energy production.

Comprehensive seed collections of these and other candidate acacia species were made by CSIRO's Australian Tree Seed Centre with financial support from AusAID and ACIAR through the "Seeds of Australian Trees" project and were made available to researchers and development workers. CSIRO staff worked with Aboriginal people when making seed collections of the target species following the Glen Helen workshop, and were able to discuss traditional Aboriginal use of acacia seeds in a traditional setting. Jock Morse and Chris Harwood were privileged to visit Niger in 1998 with two Aboriginal women, Rosie Nangala and Kay Ross, and watch them exchanging information and techniques on acacia seed collection and food preparation with the women from communities around Maradi.

Genetic research

Research on the reproductive biology of *A. colei* was carried out by Dr Toujani Abasse in the course of his PhD studies (Abasse, 2003). His results supported the findings of limited controlled pollination experiments in Australia by Maurice McDonald that this allo-hexaploid species (Moran et al. 2002) is predominantly self-fertilising. Consequently, we expect this species, and other polyploid acacia species such as *A. cowleana*, *A. elachantha*, *A. holosericea* and *A. thomsonii* to "breed true" like, for example, (polyploidy, self-fertilising) wheat strains. No inbreeding depression of yield is expected when seed is collected from isolated individual trees of these polyploid species. There is some geographically-based genetic variation within polyploid species such as *A. colei* (Moran et al. 2002; Souvannavong and de Framond 1992). However, genetic selection is easily achieved simply by collecting and propagating seed from those individuals with the most favourable characteristics. Two distinct morphological variants of *A. colei* were described (McDonald and Maslin 1997a), one with curved seed pods (*A. colei* var. *colei*) and the other with tightly coiled pods (*A. colei* var. *ileocarpa*). Extracting seed from the harvested pods of var. *colei* is less laborious, while pods of var. *ileocarpa* appear better able to retain seed for several days after the pods ripen and open, potentially an advantage for growers wishing to ensure that seed is collected and does not fall to the ground.

Several other candidate acacia species with edible seeds, including *A. saligna* (George et al. 2008) and *A. tumida* (McDonald et al. 2003) are "conventional" diploid acacia species which have mixed mating systems. *A. torulosa* most probably has a similar mating system, although this has not yet been confirmed experimentally. While these diploid species are predominantly outcrossing (and pollinated by insects) in natural stands, isolated trees are capable of self-fertilization if they cannot access outcross pollen. Selfing is expected to result in reduced vigour of the offspring, as has been demonstrated in other diploid acacia species. Genetic trials comparing the performance of different provenances from across the range of these species has demonstrated striking genetic variation in traits such as growth, stem form and seed yields in *A. torulosa* and *A. tumida* (Cunningham et al. 2008, McDonald et al. 1997) and growth, stem form and fodder quality in *A. saligna* (George et al. 2007). This provenance variation can be exploited by very simple strategies. Seed production areas can be established using trees raised from multiple-tree seed collections from the best provenances. Seed production areas can be selectively thinned to retain the very best individuals (according to the desired traits), which then cross-pollinate to produce the seed crop used for further plantings. Potential inbreeding depression should be avoided by avoiding collecting seed from reproductively isolated trees.

Silvicultural research

Australian acacia trees must be raised in nurseries prior to the rainy season, not a trivial task in village nurseries during the Sahelian dry season, with water accessed by hand from deep wells. They must then be planted out at the start of the rainy season, a period of high farming activity, and actively managed in farmers' fields, with weeding and subsequent pruning. *A. colei* trees are relatively short-lived (typically 4–6 years). Seed yields at age 20 month average only about 0.5 kg per tree in on-farm trials (Cunningham et al. 2008). According to Yates (2010) an annual seed yield of over 1 kg per tree on-farm is a reasonable expectation. However, seed collection must occur within a narrow window of a few days, otherwise the seed will fall to the ground and be lost. Seeds must be collected by hand and pre-processed by grinding and sieving prior to consumption. All this effort makes *A. colei* seed flour a relatively expensive food, both in terms of human effort per kilogram of food produced in a subsistence economy, or in monetary terms in a cash economy. Similar considerations apply to *A. torulosa* and *A. tumida*, although it is possible that one or two generations of selection for growth and fecundity in these more genetically variable species might boost seed yields.

In addition to edible seed production, there are other significant benefits ascribable to planting Australian acacia species in Sahelian countries, such as windbreak effects, wood production and increasing soil organic matter and fertility. In fact, the per-tree value of fuelwood and small building poles from "tree form" varieties of *A. torulosa* and *A. tumida* is likely to be substantially greater than that of the seed they produce, in locations where farmers have access to urban wood markets. Thus some farmers could better improve their food security by growing acacia trees, selling the wood and buying food, than by focussing primarily on seed collection and consumption/sales. Yates (2010) provides data on wood yields from *A. colei* that support this interpretation.

These more general tree-related benefits can however be supplied by other tree species, and have been realised through the practice of Farmer-Managed Natural Regeneration (FMNR), a set of techniques for restoring and managing indigenous tree cover in farming landscapes. During the two decades since the Glen Helen conference, use of FMNR has spread spontaneously across large parts of the Sahel (Reij et al. 2010).

The concept of a farmer-managed agroforestry system (FMAFS) was outlined by Cunningham et al. (2008) and is currently under test in Niger. This proposed system aims to combine FMNR practices with the systematic planting of acacia and other valuable tree species such as *Moringa oleifera* in cropping landscapes. I am keen to learn of the experience and conclusions of farmers testing this type of system.

Acacias, like any other trees, compete with annual grain crops for light, water and nutrient resources. Increasing tree stocking in a farm beyond a certain level will inevitably reduce crop yields (Stirzaker, 2010). Observations made in Niger (Harwood 1994) suggest that each *A. colei* tree requires most of the soil water resources of at least 20 square metres of weeded farmland to keep producing seed crops beyond 3 to 4 years of age. Only the edge trees of four-year-old *A. colei* plantations established at 4 m x 4 m spacing were yielding seed crops. So in simplistic terms, the tree crops in a FMAFS farm incorporating 100 acacia trees per hectare, a substantial number of planted trees of other species, and indigenous trees regenerated through FMNR, will consume maybe half of its available soil water resources, making them unavailable to "conventional" grain crops such as millet and sorghum. The farmer thus has to make a choice about the respective net returns from trees and grain crops in the farming system, for improving his/her livelihood (Dixon 2001).

On the basis of the seed yields discussed above, a one-hectare FMAFS farm appears unlikely to yield more than about 50–100 kg of acacia seeds per year, on the data gathered thus far – a useful additional supply of food, but not enough to transform food security. However, grain yields from crops grown near to acacia trees, but not within their range of immediate competitive influence, may be higher than those obtainable in a bare treeless field, because of the positive influences of the trees such as wind-break effects. Growing trees and crops in rotation, bringing the benefits of nitrogen fixation and increased soil organic matter to degraded farmland, is another option. The merits of incorporating trees into farming systems depend in large part on land availability. If a farmer can access sufficient land, a given area of cereal crops can be "spaced out" over a larger land area between rows of trees, avoiding the competitive effects of trees by not growing the crops immediately under/adjacent to them, while accessing the products and beneficial effects of the trees.

Another factor that needs to be considered is the effect of nematodes on the growth and nitrogen-fixing capability of acacia trees. Researchers in Senegal have intensively studied the interaction of nitrogen fixation by *A. holosericea* (probably *A. colei*), and the pathogenic root-knot nematode *Meloidogyne javanica* (Duponnois et al. 1995, Duponnois et al. 1999). Nematode populations built up through their association with acacia trees in FMAFS farms might adversely affecting food crop production. This possibility needs to be kept under review, and attention to the relevant scientific research is warranted.

Acacia saligna in Ethiopia

Acacia saligna is widely planted in upland regions of northern Ethiopia. This species was not considered in the Glen Helen workshop, which focussed on subtropical and tropical acacia species adapted to Sahelian conditions. *A. saligna* occurs naturally at temperate latitudes (27–35ºS) in south-west Western Australia with climates having a winter rainfall maximum. While it would certainly not perform well in the Sahel, it has proved well-adapted to the temperate upland climate of northern Ethiopia. Summary information on *A. saligna* was assembled in the book *Edible Wattle Seeds of Southern Australia* (Maslin et al. 1998). Seeds of this species are known to have been eaten by Aboriginal people. Interestingly, its phyllodes have some nutritional value as fodder for sheep and goats, and there is also a report of *A. saligna* seeds having been used to feed goats in Cyprus. It is widely grown in Mediterranean countries and is a major weed in the south of South Africa. Substantial additional research has been done on *A. saligna* in Western Australia to evaluate its potential as a plantation species for hydrological control, fodder and biomass production in the Western Australian wheatbelt (George et al. 2007). Different subspecies have been identified. *A. saligna* was introduced to Ethiopia many decades ago, and it would be instructive to compare the land races that have developed there with the subspecies and provenances now identified in the natural range. It may well be that improved performance of *A. saligna* in Ethiopia could be obtained through new introductions of varieties more appropriate for the targeted end uses, although replacing the existing land race would likely be a slow process.

In Tigrai, Ethiopia *A. saligna* has been promoted by forestry agencies and grown widely for “land rehabilitation” on non-arable hillsides. Large stands of trees are in place, and producing large quantities of seeds, on hillsides adjacent to large human populations who in times of drought are vulnerable to famine. This situation appears, at least superficially, to offer an immediate prospect of improving food security, without requiring change in farming practices or in the agricultural landscape.

Here, future R&D can focus more on the seeds as a food, although the weediness potential of this species in Ethiopia needs to be kept under close review. Nutritional and toxicological research needs to be undertaken on the seeds. An understanding of seed yields per tree, and the effort required to pick seed crops, extract and clean seeds, per kilogram, will give us an idea of the attractiveness of *A. saligna* as an additional food source, in both subsistence and cash economies. The experience in the Sahel with *A. colei* seed suggests that attention to the possibility of developing the prospective new food as a business, through genuinely participatory research with prospective entrepreneurs, might be a rewarding approach.

Conclusion

On reflection, I would say that the well-motivated desire to develop acacia seeds as a food source in regions of poor food security such as the Sahel led to a somewhat unbalanced research effort, which addressed most of the issues identified in 1991 at the Glen Helen workshop. Admirable effort has gone into researching the nutritional benefits and potential nutritional problems associated with acacia seed consumption. While the technical feasibility of producing significant quantities of edible and nutritious acacia seeds from the target species in Sahelian countries has been established, it seems that farmers have not yet perceived a clear net benefit from incorporating these acacia species into their farming systems. Agronomic trials suggest that yields of seed are relatively modest (unlikely to consistently exceed 50–100 kg per hectare per year in farming systems). The required inputs, expressed as hours of effort per kilogram of seed flour produced, make the seed relatively expensive. Unless a commercial demand for acacia seeds can be developed, it seems unlikely that Australian acacia species will be widely adopted as a major food source in the Sahel.

I suggest that any future agronomic research should be participatory, largely driven by potential farmer-adopters, and should focus on the farm-level economics (inputs, compared to outputs of seed, fuelwood and other benefits) of growing Australian acacia species in Sahelian farming systems. The experience gained in the Sahel should prove very valuable in guiding research and development of *A. saligna* as a prospective new food source in the Ethiopian highlands.

References

Abasse, T. (2003b) Reproductive Biology of *Acacia colei* (Maslin and Thomson) in Niger Republic. Phd thesis. University of Ibadan, Ibadan, Nigeria.

Cunningham, P., Nicholson, C., Yaou, S., Rinaudo, T., Harwood, C.E. (2008) Utilization of Australian acacias for improving food security and environmental sustainability in the Sahel, West Africa.

International Symposium *Underutilized plants for food, nutrition, income and sustainable development*. Arusha, Tanzania, March 2008. International Centre for Underutilized Crops, Colombo, Sri Lanka. http://www.icuc-iwmi.org/Symposium2008/4-4-Cunningham.pdf

Dickson, J. (2001) Farming systems and poverty. FAO, Rome. http://www.fao.org/farmingsystems/

Duponnois, R., Neyra, M., Senghor, K., Ba AM (1999) Effects of the root-knot nematode *Meloidogyne javanica* on the symbiotic relationships between different strains of rhizobia and *Acacia holosericea* (A Cunn. Ex g. Don). *European Journal of Soil Biology* 35 (2):99-105.

Duponnois, R., Senghor K, Mateille T (1995) Pathogenicity of *Meloidogyne javanica* (treub) chitw – to *Acacia holosericea* (A Cunn ex g Don) and a-seyal (del). *Nematologica* 41 (4):480-486

George, N., Byrne, M., Maslin, B., Yan, G. (2006) Genetic differentiation among morphological variants of *Acacia saligna* (mimosaceae). *Tree Genet Genomes* 2 (2):109-119

George, N., Byrne, M., Yan, G. (2008) Mixed mating with preferential outcrossing in *Acacia saligna* (Labill.) h. Wendl. (leguminosae : Mimosoideae). *Silvae Genetica* 57 (3):139-145

George, N., Henry, D., Yan, G., Byrne, M. (2007) Variability in feed quality between populations of *Acacia saligna* (labill.) h. Wendl. (Mimosoideae) – implications for domestication. *Animal Feed Science and Technology* 136 (1-2):109-127.

Harwood, C.E. (1994) Human food potential of the seeds of some Australian dry-zone acacia species. *Journal of Arid Environments* 27 (1):27–35.

Harwood, C.E., Rinaudo, T, Adewusi, S (1999) Developing Australian acacias as a human food source in the Sahel. *Unasylva* 196; 57–64

House, A.P.N., Harwood, C.E. (1992) Australian dry zone acacias for human food. Proceedings of a workshop held at Glen Helen, Northern territory, Australia, 7–10 August 2001. CSIRO, Canberra

Maslin, B.R., McDonald, M.W. (1996) *Acacia thomsonii* (Leguminosae: Mimosoideae: *Acacia* section *juliflorae*), a new species from the tropical dry zone of australia. *Nuytsia* 10 (3):443–449

Maslin, B.R., Thomson, L.A.J. (1992) Re-appraisal of the taxonomy of *Acacia holosericea*, including the description of a new species, *A. colei*, and the reinstatement of *A. neurocarpa*. *Australian Systematic Botany* 5 (6):729–743. doi:10.1071/sb9920729

McDonald, M.W. (2003) Revision of *Acacia tumida* (Leguminoseae : Mimosoideae) and close allies, including the description of three rare taxa. *Australian Systematic Botany* 16 (2):139–164

McDonald, M.W., Butcher P.A., Bell, J.C., Nguyen, C.V. (2003) Clinal variation and genetic divergence in *Acacia tumida* (Mimosaceae). *Australian Systematic Botany* 16 (1):57–68

McDonald, M.W., Harwood, C.E., Whitfeld, S.J. (1997) Morphological variation in *Acacia tumida* and implications for its utilisation. Recent developments in acacia planting. Maslin, BR; Thomson, LAJ; McDonald, MW; Hamilton-Brown, S. (1998). *Edible Wattle Seeds of Southern Australia: A Review of Species for Use in Semi-Arid Regions.* CSIRO, Melbourne

McDonald, M.W., Maslin, B.R. (1997a) *Acacia colei* var. *ileocarpa* (leguminosae: Mimosoideae), a new taxon from the tropical dry-zone of north-west Australia. *Nuytsia* 11 (2):219–223

McDonald, M.W., Maslin, B.R. (1997b) A reappraisal of *Acacia cowleana* and allied taxa, including the description of a new species, *A. elachantha*, from the tropical dry-zone of Australia. *Australian Systematic Botany* 10 (3):303–320

Moran, G., Thomson, L., Grant, J., Bell, C. (1992) Distribution of genetic variation within two dry-zone acacia species and implications for the genetic improvement. p. 74–81 in House, A.P.N. and Harwood, C.E. (1992).

Reij, C., Tappan, G., Smale, M. (2010) Re-Greening the Sahel: Farmer-led innovation in Burkina Faso and Niger. International Food Policy Research Institute http://www.ifpri.org/sites/default/files/publications/oc64ch07.pdf

Souvannavong, O., and de Framond, H. (1992) Performance of dry zone acacia species and provenances recently introduced to the Sahel. p. 82–92. in House., A.P.N. and Harwood, C.E. (1992).

Stirzaker, R. (2010) *Out of the Scientist's Garden*. CSIRO Publishing, Melbourne.

Yates, P. (2010) *Australian acacias: The potential to combat child malnutrition, build agricultural resilience and support adaptation to climate change in semi-arid Africa.* Charles Darwin University.

Understanding Acacia saligna

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This segment commences with an introduction from Bruce's presentation at the workshop, followed by a paper containing detailed information.

Effective taxonomy underpins effective utilisation

There are nearly 1500 different entities of acacias in Australia. After a terrific introduction by Chris Harwood, I would like to shift the focus from Africa to Australia – from cultivated stands to natural stands, from *Acacia colei* to *Acacia saligna*. In fact *saligna* didn't even get mentioned in the Glenn Helen workshop 20 years ago. I think Chris Harwood, Jock Morse and I were the only ones in this room at Glen Helen. Talking about *saligna,* we are also shifting the emphasis from northern Australia to southern Australia and I am hoping this very general and quick talk will provide a basis for the talks on *Acacia saligna* that I am looking forward to hearing after this one. A number of you here already know that *Acacia saligna* is a variable species. It's one that's endemic in south-western Australia where it occurs primarily in the 250 to 1200 mm rainfall zone. I want to concentrate on the variation within *Acacia saligna* in its natural habitat. I know a lot of you may be familiar with this, but what you may not be familiar with is the full range that exists. You may also not be familiar with its variation in its taxonomic context. I won't spend too much time on it, but I do think it's important to have some understanding of the taxonomic context and that the various entities we will be talking about do reside in genus. I will also talk a bit about the provenance variation within the species to give you a broad overview. In this work I have been very ably assisted with Morris McDonald who is not with us today, and Wayne O'Sullivan (who is), and I thank them both very much for their assistance. They are the co-authors of the paper that follows. Morris and I also have in progress a taxonomic revision of *Acacia saligna*. Let's just move on firstly and deal with the taxonomic side of things.

Understanding Acacia saligna

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Introduction

Acacia saligna is an extremely polymorphic species that is endemic in south-west Western Australia where occurs principally within the 250 to 1200 mm rainfall zone. An overview of the biology, ecology, utilisation, cultivation, etc. of the species is provided in Midgley & Turnbull (2003) and Maslin & McDonald (2004). An excellent, more comprehensive review of these and other aspects of *A. saligna* is currently in preparation (O'Sullivan et al., in prep.). *Acacia saligna* has had a relatively long history of cultivation with around 600,000 ha established worldwide (Griffin et al. 2011), and in a number of areas it has become invasive, for example, it is a serious environmental weed in South Africa (Henderson 2001). Further useful information concerning *A. saligna* is available on the WorldWideWattle website http://www.worldwidewattle.com/infogallery/projects/saligna.php. Many additional useful references concerning *A. saligna* are provided in the above review sources. It should be noted, however, that the utility of the information in these works is often diminished because it is not known to which of the four subspecies it applies.

Taxonomy

Note. A revision of A saligna *is currently in progress (Maslin & McDonald, in prep.). While four main taxonomic entities for the species have been recognised in this study, a final decision on their rank has yet to be made. Nevertheless, for the purpose of this handout these entities will be called subspecies. This rank may possibly change in the future.*

As discussed by Maslin (2002) utilisation and domestication work will be more effective if it based on a sound taxonomy of the species under investigation. Taxonomy defines meaningful biological entities (e.g. species, subspecies) and provides names for them; it is these names that are the "hooks" by which information is stored, retrieved and exchanged concerning the entities. Taxonomy also produces classifications which aim to bring related entities together into groups which are arranged in a hierarchical fashion. An effective classification would be expected to have some predictive power, for example, if a particular species or subspecies has some quality or characteristic useful for domestication then it might be expected that other species or subspecies in the same group will also possess these attributes. These two aspects of taxonomy, namely, the provision of named entities which are arranged in a meaningful classification, have particular relevance to the present discussion of *A. saligna*.

Current taxonomic research indicates that the variation within the highly polymorphic *A. saligna* is best accommodated by four subspecies, namely:

1. subsp. *saligna* (referred to as the "cyanophylla" variant of *A. saligna* in Maslin & McDonald 2004 and elsewhere);
2. subsp. *pruinescens* (referred to as the "Tweed River" variant of *A. saligna* in Maslin & McDonald 2004 and elsewhere);
3. subsp. *lindleyi* (referred to as the "typical" variant of *A. saligna* in Maslin & McDonald 2004 and elsewhere);
4. subsp. *stolonifera* (referred to as the "forest" variant of *A. saligna* in Maslin & McDonald 2004 and elsewhere).

Until recently these subspecies were defined by a combination of phyllode and bark characters. However, because the phyllodes of *A. saligna* are very variable and bark attributes are not often recorded by collectors, it was often difficult using these characters to distinguish the subspecies. Fortunately some recently discovered inflorescence characters (especially bud shape, size and colour, and the timing of bud-burst) have proved very useful and reliable in helping to identify the subspecies (see p. 25). Notwithstanding the usefulness of these characters it is regrettable that they are available on plants for only a few months of the year.

The above-mentioned inflorescence characters enable the four subspecies of *A. saligna* to be classified into two groups, each group containing two subspecies, namely, subsp. *saligna* + *pruinescens* and subsp. *lindleyi* + *stolonifera*. This pattern of relationship among the subspecies is supported by recent molecular data (e.g. George et al. 2006, Miller et al. 2011). The relevance of this classification is that plant morphological and behavioural characteristics that have relevance to utilisation/domestication might also align according to this same pattern of subspecies relationships. This matter bodes further consideration because it may well have practical implications when selecting provenances for development. Consider root-suckering, for example. This attribute is considered disadvantageous if one is wishing to develop structured "plantation crops" (for woody biomass production for example) whereas it is highly advantageous if one is seeking to develop self-sustaining "fodder crops". Field observation of native stands of *A. saligna* suggest that root-suckering occurs at a low frequency in subsp. *saligna* + *pruinescens* but is common in subsp. *lindleyi* + *stolonifera*.

Utilisation and domestication

One of the great strengths of *A. saligna* as a candidate for utilisation/domestication is the considerable provenance variation that occurs within each of the four subspecies. Because of this variation there exists within each subspecies a large pool of genetic resource upon which to draw in order to select entities that might be suitable for delivering a range of different end products.

The first critical step in the process of utilisation/domestication is the selection of appropriate provenances to work with. Therefore, on the following pages we illustrate some of the variation observed within plants of *A. saligna* in its native habitat and suggest some possible end-products based on these plants. When considering these entities as possible candidates for utilisation/domestication there are two important points that must always be kept in mind:

1. These plants are wild organisms, ones which by their very nature are variable and unpredictable. Therefore, one cannot necessarily expect such plants to behave in cultivation in the same way as they do in the wild, especially if they are grown from seed collected from the wild.
2. Regardless of how a plant grows in the wild, its ability to deliver specific end-products will never be known until it is trialled at sites within the environment where it is intended to be used.

Concluding remark

Much work involving *A. saligna* has been undertaken in recent decades. Today there are projects involving the utilisation/domestication of the species in places like sub-Saharan Africa and Chile, and its control/eradication in places like South Africa and the eastern Mediterranean. It is expected that these and other activities involving *A. saligna* will benefit from the taxonomic clarification of the species and from the documentation of provenance variation within the four subspecies that are now recognised.

References

George, N., Byrne, M., Maslin, B.R. and Yan, G. (2006). Genetic differentiation among morphological variants of *Acacia saligna* (Mimosaceae). *Tree Genetics & Genomes* 2(2): 109–119.

Griffin, A.R., Midgley, S.J., Bush, D., Cunningham, P.J. and Rinaudo, A.T. (2011). Global uses of Australian acacias – recent trends and future prospects. *Diversity and Distributions* 17(5): 837–847.

Henderson, L. (2001). *Alien weeds and invasive plants. A complete guide to declared weeds and invaders in South Africa.* Plant Protection Research Institute Handbook No. 12. (Department of Agriculture and Department of Water Affairs and Forestry: South Africa.)

Maslin, B.R. (2002). The role and relevance of taxonomy in the conservation and utilisation of Australian acacias. *Conservation Science Western Australia* 4(3): 1–9.

Maslin, B.R. and McDonald, M.W. (2004). AcaciaSearch. E*valuation of acacia as a woody crop option for southern Australia.* Report to the Rural Industries research and Development Corporation. Publication No. 03/017. Canberra, pp. 263.

Maslin, B.R. and McDonald, M.W. (in prep.). A taxonomic review of *Acacia saligna* (Leguminosae: Mimosoideae).

Midgley S.J. and Turnbull J.W. (2003). Domestication and use of Australian acacias: case studies of five important species. *Australian Systematic Botany* 16: 18–102.

Millar, M.A., Byrne, M. and O'Sullivan, W. (2011). Defining entities in the *Acacia saligna* (Fabaceae) species complex using a population genetics approach. *Australian Journal of Botany* 59: 137–148.

O'Sullivan, W., Huxtable, D., George, N. and Bartle, J. (in prep.). Review of *Acacia saligna* (Koojong Wattle) and its Potential for Domestication for Western Australian Dryland Farming Systems.

Bud morphology

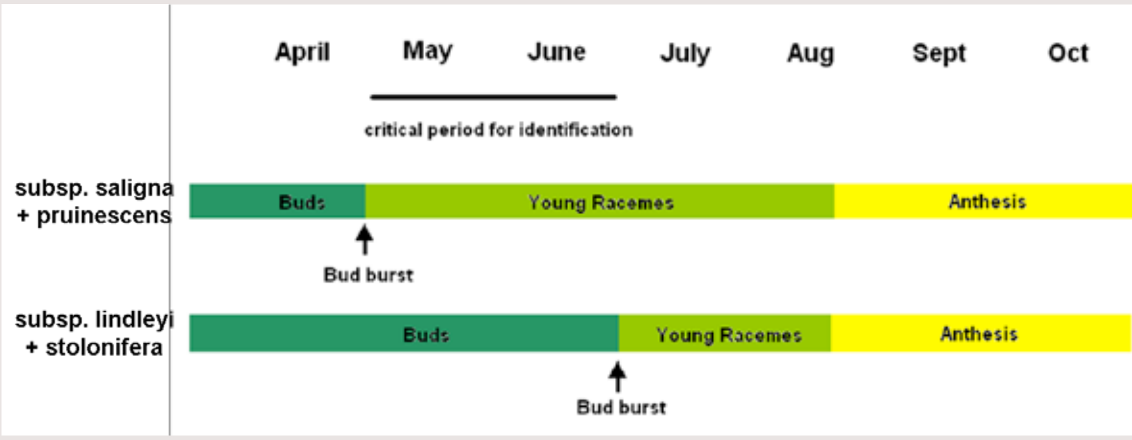

Subsp. *saligna* (left) and subsp. *pruinescens* (right). Inflorescence buds ±elliptic, broadest in middle, obtuse to sub-acute.


Subsp. *lindleyi* (left) and subsp. *stolonifera* (right). Inflorescence buds conical, broadest below middle, acute to acuminate.

Phenological sequence

Buds Bud burst Young racenes Anthesis

Phenology



Acacia saligna subsp. *saligna*

Potential uses based on observation of natural stands. Selection of appropriate provenance will be critical to maximizing productivity.

Acacia saligna subsp. *saligna* is perhaps the most commonly utilised of the four subspecies. It produces the largest plants with the highest woody biomass and seed yields. Low suckering propensity is advantageous in some applications.

Seed production. Abundant seed production. Size of plant may constrain harvest.

Animal feed. Abundant foliage but variation in quality largely unknown. Tall plants will need lopping to make foliage accessible to animals.

Fuel wood. Good woody biomass production from an early age.

Other wood products. High woody biomass yield and largest diameter timber. Some provenances show good (straight) stem form.

Environmental remediation. Fast growth rate, large plant size, good windbreak. Weed risk associated with high seed production.

22-month-old plants in cultivation

Acacia saligna subsp. *pruinescens*

Potential uses based on observation of natural stands. Selection of appropriate provenance will be critical to maximising productivity.

Acacia saligna subsp. *pruinescens* is relatively uncommon in nature and is seemingly the subspecies most susceptible to gall rust (uromycladium). Adult plants generally have poor stem form.

Seed production. Seemingly low.

Animal feed. Adolescent plants have abundant foliage; mature plants have lighter crowns.

Fuel wood. Good woody biomass production at an early age. Grow form of adolescent plants facilitates easy harvest.

Other wood products. Adolescent plants show moderately good stem form but form deteriorates with age of plant.

Environmental remediation. Seemingly low.

Acacia saligna subsp. *lindleyi*

Potential uses based on observation of natural stands. Selection of appropriate provenance will be critical to maximising productivity.

Acacia saligna subsp. *lindleyi* is the most widespread and variable of the four subspecies, and it grows in the generally driest environments.

Seed production. Production can be moderately high but seed yield per plant can be constrained by often shrubby habit of plants. This habit may facilitate seed harvest.

Animal feed. Moderate suckering and shrubby habit may be advantageous.

Fuel wood. Reasonable wood volume achieved under good growing conditions (i.e. appropriate water availability).

Other wood products. Straight stem forms occur in a few provenances.

Environmental remediation. Shrubby habit and moderate suckering may be useful for soil binding. Moderate suckering a potential weed problem.

Acacia saligna subsp. *stolonifer*

Potential uses based on observation of natural stands. Selection of appropriate provenance will be critical to maximising productivity.

Acacia saligna subsp. *stolonifera* occurs in the wettest part of the species' geographic range. Unlike other subspecies it often occurs as a forest understory plant. It has a high suckering propensity and low seed production.

Seed production. Poor.

Animal feed. High suckering propensity may confer advantage in development of sustainable grazing systems.

Fuel wood. Often low to moderate woody biomass production.

Other wood products. Occasionally good, straight stem form in clonal clumps.

Environmental remediation. Can form dense thickets due to suckering; good for soil-binding but potential weed risk.





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Wattle as food: Nutritional and toxic considerations

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Abstract

Seeds of certain Australian acacia species (*A. colei, A. tumida, A. torulosa, A. elancantha* and *A. coriacea*) have potential as a food source in tropical semi-arid Africa. This paper presents information on the potential of some of these acacia species as human food and summarises information on the chemical composition and the nutritional studies conducted over the past 20 years.

Chemical analysis of the seeds of acacia revealed a rich source of protein and vitamins and a balanced amino acid profile with tryptophan as the first limiting amino acid using protein digestibility modified amino acid score and a moderate level of good oil. Nutritional evaluation of *A. colei* and *A. tumida* at 20% incorporation in the rat diet revealed a fairly good source of protein (PER 1.1) but its performance was not as good when incorporated at 40% or as the sole source of protein (47% incorporation). Complementation between *A. colei* seed flour and the commonly eaten cereals (acha, brown *fonio*, millet and sorghum) or cassava revealed both acha and brown *fonio* to give the best complementation with *A. colei,* probably due to the latters' high methionine content. In vivo studies using rats conclusively demonstrated methionine as the first limiting amino acid. Human feeding trials indicated *A. colei* to be a good source of energy and other nutrients with no discernible toxicological effect. Analysis of anti-nutritional factors and toxicological studies also revealed the seeds to be safe for human consumption at 25% incorporation. However, the presence S-carboxyethylcysteine, a compound structurally similar to the sulphur amino acids (methionine and cysteine), affects the metabolism of the sulphur amino acids.

Introduction

Hunger, famine, malnutrition and their attendant diseases are major public health issues in the semi-arid Sahelian region of West African where mean annual rainfall is below 600 mm. In these tropical environments, millet and sorghum are the main food sources and account for most of the area under cultivation. These cereals require about three months of consistent precipitation to yield well. Serious crop failures and subsequent food shortages have occurred in the Maradi district in the south of the Niger Republic in 1973–75, 1984, 1988, 1994, 1996, 2002, 2005 and 2009 as a result of drought and other factors such as pest attack on crops. Drought and desertification are known to promote a host of calamities that range from loss of biodiversity, depletion of water resources, destruction of arable land, reduction in soil fertility and global warming. All these could cause famine, diseases, reduction in standard of living and death of humans and livestock as witnessed in some parts of Africa between 1968 and 1974 when hundreds of thousands of people and millions of animals perished due to drought and desertification (McHarry et al., 2002). During famines, rural people resort to eating “famine foods” including bran, grass, tree bark and leaves of trees.

The genus acacia includes many drought-resistant species. There are over 50 acacia species identified to be part of the diets of traditional Australian Aborigines (Devitt, 1992). Some of these Australian acacia species have been introduced into Sahelian region of West Africa where rainfall is less than 600 mm per annum and found to thrive with heavy yields of seeds (Rinaudo et al., 2002; Harwood et al. 1999). Of all the Australian acacia species tried in Maradi, Niger Republic, *A. colei* and *A. tumida* demonstrated the highest survival rate and rapid growth on a wide range of soil types (Cossalter, 1987; Rinaudo et al., 2002). These attributes make these Australian acacia species potential candidates for combating the problems of famine, drought and desertification.

The seeds of *A. colei* are known to have been eaten, as a ground-up paste, in the traditional diets of Australian Aboriginal people (Harwood 1994), and this use continues until today among some rural Aboriginal communities in north-west Australia (J. Morse, pers. comm. 1996). Villagers in Niger collaborating with the Maradi Integrated Development Project (MIDP), a non-government rural development program, became aware of this potential food source in 1990. Since then, MIDP has studied the seed production of *A. colei* in local plantings and local people have developed over 20 palatable foods which incorporate acacia seed flours into their traditional millet and sorghum-based recipes.

The purpose of the paper is to provide nutritional and toxicological information on the potential of some of the acacia seeds (especially *A. colei* and *A. tumida*) as famine food.

Chemical composition and nutritional value of acacia seeds

Chemical composition

Our research group has carried out significant compositional studies on *A. colei* and *A. tumida* seeds. The results from these studies revealed the potential of these acacia species as human food. The investigations showed the seeds to compare favourably with other legumes and even better in some nutritional parameters (Adewusi et al., 2003; Falade et al., 2005; Falade et al., 2008a; Falade et al., 2008b).

Macronutrients

Protein

Protein is an important component of food that is essential for growth and maintenance. Protein energy malnutrition (PEM) is still an important health problem in the developing countries. The introduction of plant foods rich in protein will go a long way to solving its malnutrition among the poor people living in the developing countries. Crude protein (CP) content of 20.6 to 23.0% was reported for *A. colei* and three provenances of *A. tumida* (Table 1). The CP of 22.3% reported for sieved *A. colei* by Falade, et al., (2005) was not significantly different from 21.4% reported by the same authors a few years later (Table 3).

The marginal difference could be due to the fact that the seeds were not harvested in the same year and also probably from different trees. The high CP content of acacia seeds indicated that acacia could replace cowpea and other legumes (Adewusi and Falade, 1996) as a source of protein in the diets of people of the arid zone of Africa. The daily consumption of as low as 100 grams of these acacia seeds could provide about 40–50% of the recommended dietary intake (RDI) for protein (NHMRC, 1987). Crude protein analysis, however, will only provide a rough estimation of protein since some plant foods contain non-protein nitrogenous compounds, which will over-estimate the protein level. Murray and McGee (1986) have observed that acacia seeds contain a substantial level of non-protein nitrogen. The same trend has been equally observed for these two acacia species – 17.5% true (extractable) protein was reported for *A. colei* and a range of 11.5–12.6% extractable protein was obtained for the three cultivars of *A. tumida* seeds (Table 1). This was about 22–45% lower than the crude protein content of *A. colei* and *A. tumida* seeds, representing an over-estimation of this important parameter. The amino acid profile of these acacia species revealed *A. tumida* to be more balanced than in *A. colei* and tryptophan was the first limiting amino acid in both seed samples using the chemical score method (Table 2). The use of protein digestibility corrected amino acid score (FAO/WHO, 1991) for *A. colei* seed flour revealed histidine (99%) has the highest, while tryptophan has the lowest (50%) chemical score (Table 2). The results also showed sulphur amino acids and threonine as the joint second limiting amino acids (61%).

Carbohydrate

Carbohydrates, especially glucose and glycogen, serve as the major source of readily available energy for human body. They are also major sources of fuel to the brain (Brand and Maggiore, 1992). The knowledge of levels of carbohydrate in foodstuffs is important to those who are watching their weight and also to diabetic patients.

The reducing sugar content of these acacia species ranged between 31.1 and 54.5 g/kg on dry weight basis while total sugar content was 139.6–154.3 g/kg (Table 1). The total sugar was within the range of 87–67 g/kg reported for legumes (Adewusi and Falade, 1996). Since taste is partially dependent on the amount of total sugar present, replacement of the traditional sources of carbohydrate with acacia may not significantly alter the taste of the modified diets of the people of the arid zone. This could also account for the willingness of the Maradi people to incorporate *A. colei* into their local recipes (Adewusi et al., unpublished paper). The starch content was observed to vary between 255.9 and 323.4 g/kg (Falade et al., 2005).

Fibre

Dietary fibre is defined as the portion of plant foods that cannot be digested by human digestive secretions in the digestive tract (Deis, 1999). Dietary fibre is made up of cellulose, hemicellulose, hexosans, pectin substances, gum, mucilage and lignin. The major function of fibre in the food is the maintenance of the health of the gastrointestinal tract (CFW 2001; Adegoke et al., 2006). Total dietary fibre content (Table 1) was 29.5% for *A. colei* and 28.5–32.7% for three provenances of *A. tumida*. The dietary fibre content of *A. colei* was significantly higher than those found in cereals (0.5–9.8%) (Table 3). It is therefore expected that the incorporation of acacia seeds into the traditional fare of the people of Maradi will increase their total dietary fibre intake. Our human feeding trial revealed that the incorporation of *A. colei* at 25% level led to daily intake of 171 g of dietary fibre in males which was 80% higher than in the traditional fare while it was 170 g in females which was 106% higher than in the traditional fare, (Adewusi et al., 2006a). Falade et al., (2005) observed that the incorporation of acacia seeds in to human diets would increase the level of soluble fibre intake. Soluble fibre is known to decrease postprandial glucose and insulin concentration (Mayer et al., 2000). This means that the incorporation of acacia seeds into the diets of diabetic patients could be of tremendous benefit. Although fibre has beneficial effects, it is not without its adverse effects. For example, fibre is known to bind minerals and also reduces protein and carbohydrate digestibility of food (Adewusi and Ilori, 1994; Falade et al., 2005).

Fat and fatty acid composition

Fat, which is believed to be surplus in Western countries, is in short supply in many countries of Africa (Brand and Maggiore, 1992). Fat (ether extract) content of these acacia seeds was moderate (7.7–11.9%) (Table 4). Brand et al., (1985) had earlier reported a range of 7.8 to 10.2% for some acacia species. This range has been observed to be higher than in most legumes (Brand and Maggiore, 1992) and also reported to be palatable (Brand and Cherikoff, 1985). All these show that acacia could be a good source of vegetable oil. Our earlier investigation on physiochemical properties of acacia seed oils (Table 4) revealed acacia oils to be better than groundnut oil in almost all the nutritional parameters investigated. The properties of these oils also showed that the oils could provide good feedstock for the soap industry, suitable for use as lubricant at low temperature and could be used as biodiesel (Falade et al., 2008a). Linoleic acid is the predominant fatty acid in acacia, constituting 55.9% of the *A. colei* and 50.1% of *A. tumida* seed oil (Adewusi et al., 2003). The seeds also have high levels of oleic acid (18 and 23.5%) for *A. colei* and *A. tumida*, respectively, while palmitic acid was low at 11.4 and 14.4% for *A. colei* and *A. tumida*, respectively (Adewusi et al., 2003). The high level of the polyunsaturated fatty acids show that acacia seed oils could be suitable for human consumption from the nutritional viewpoint.

Micronutrients

Vitamins

The vitamin A precursors (α-carotene and β-carotene) were very low in *A. colei* seed flour, which was <5 μg/100 g in both precursors (Adewusi et al., 2003). The recommended daily intake (RDI) of this vitamin, known to enhance immunity and also for the treatment and prevention of cancer (Adewusi and Bradbury, 1993), is 600–800 μg RE for adult (FAO/WHO, 1988) acacia is therefore not a good source of vitamin A.

Thiamine (Vitamin B1) was relatively high in *A. colei* seed flour (0.34 mg/100 g), and between 300–400 g of the *A. colei* could supply the RDI of 1.1 mg / day for men (NHMRC, 1991; Adewusi et al., 2003). The thiamine content of this acacia was reported to compare well with the levels obtained for some cereals (FAO, 1968).

Riboflavin (vitamin B2) was 0.36 mg/100g in *A. colei* seed (Adewusi et al., 2003). This value was higher than in conventional root crops reported to range between 0.06–0.23 mg/100 g (Bradbury and Holloway, 1988).

The niacin content of *A. colei* was 4.2 mg/100 g while pantothenic acid and α-tocopherol are 1500 μg/100 g and 0.30 mg/100 g, respectively (Adewusi et al., 2003).

Minerals

The mineral analysis of these acacia seeds in our laboratory revealed potassium to be the predominant element (Adewusi et al., 2003) which is in agreement with the finding of Brand and Maggiore (1992). The iron content varied between 18 and 54.4 mg/100 g, higher than a range of 5–12 mg/100 g reported for legume seeds (Adewusi and Falade, 1996). This shows that these acacia seeds will be better sources of this important element. Magnesium, calcium and zinc were also observed to be in high concentration in these acacia species (Adewusi et al.,

2003). Heavy metals (lead, cadmium and cobalt) only exist in traces or are not detectable and would not constitute any toxicity problem (Table 5).

Toxic and anti-nutritional factors

Phytochemical screening of *A. colei* and *A. tumida* for alkaloids and saponins revealed that the samples did not contain alkaloids but were positive to the saponin test (Falade et al., 2005). Saponin has been reported to impair iron absorption (Price et al., 1989) and to form complexes with cholesterol, which is then excreted from the body (Jacobberger, 2001).

Tannins are considered to be anti-nutrients due to a range of their adverse effects which include among others reduction in feed intake and conversion, reduction of bioavailability of micronutrients, liver damage and reduced growth (Chung et al., 1998; Adewusi and Falade, 1996). Tannin content of these acacia species (Table 1) ranged between 66.0 and 86.7 mg/g. This range was higher than the 0.9–3.9 mg/g reported for some Nigerian legumes (Adewusi and Falade, 1996). The high levels of the compounds in acacia show that tannins will be an important factor in the assessment of the nutritional value of these seeds. Heat treatment has been observed to reduce this anti-nutrient through polymerisation (Adewusi and Falade, 1996), hence it is expected that cooking will reduce its level in acacia-based diets.

Phytate, known to impair minerals' availability and block the action of a number of digestive enzymes such as pepsin (Adewusi and Falade, 1996; Knuckles et al., 1989), was very low in these acacia seeds (0.03–0.1 mg/g) (Table 1). The value was lower compared with a range of 1.7–3.8 mg/g reported for sorghum (Doherty et al., 1982). This factor is not likely to play a significant role in the nutritive value of these acacia samples.

Trypsin inhibitors (TIU) are anti-nutritional factors associated with pancreatic enlargement, reduced digestibility, reduced absorption of amino acids and reduced bioavailability of essential minerals (Gatel and Grosjean, 1990). The range of the factor (18–24.5 TIU/g) (Table 1) was low when compared with a range of 6,700–23, 300 TIU/g reported for cowpea (Adewusi and Osuntogun, 1991). This means that this factor is unlikely to pose any problem in the utilisation of the acacia seeds for food.

Oxalate is implicated as a source of kidney stones (Chai and Liebman, 2004). The oxalate content of these acacia was fairly high (2.17–2.39 g/100 g) compared with oxalate content of some Nigeria vegetables (Falade et al., 2004) but significantly lower than values of 10.2 and 32.6 g/100 g reported for cabbage and sweet potato respectively (Santamaria et al., 1999).

Nutritional evaluation of acacia seed

Diets incorporating 42–50% seed flour of *Acacia colei* and *A. tumida* and protein-free and casein-control diets were tested in a 28-day nutritional study using six rats per treatment. Two of the animals fed the unprocessed *A. colei*-based diet and one of those fed *A. colei* water-processed to remove seed coat fragments died, while all the others survived the experimental period. The *A. colei*-fed animals that survived gained weight and recorded PER (protein efficiency ratios) of 1.4 (unprocessed) and 0.91 (processed) respectively. Rats on the *A. tumida* diet recorded a PER of 1.4 and appeared to be in robust health (Table 6). Those on a casein-control diet had a PER of 0.54 and lower growth rates. Supplementation of processed *A. colei* and *A. tumida*-based diets with 0.2 % DL-methionine significantly increased weight gain, PER and net protein retention. Enzyme indicators did not indicate any liver disorder of acacia-fed animals while a mild form of nephrotoxicity was indicated only by the initial high levels of acid and alkaline phosphatase in the urine of *A. colei*-fed rats and a high urinary lactate dehydrogenase level in the animals fed processed *A. colei*-based diets. Haematological results showed that anaemia was apparent in rats fed unprocessed *A. colei* and the natural defence system appeared under stress as indicated by the below-normal white blood cell and lymphocyte counts in the *A. colei*-fed animals.

Nutritional evaluation of *A. colei* and *A. tumida* seeds fed at 20 and 40% level, carried out in our laboratory by feeding Wistar strain weanling rats for 13 weeks, indicated that the seeds support a fair growth rate and are essentially safe for human consumption (Table 7).

A combination of acacia, legumes and cereals locally available in Nigeria and Niger Republic were trialled in a complementation study using laboratory rats to test the best combination between the protein, lipid and dietary fibre component of traditional sources of energy such as millet and sorghum with *A. colei* seed flour (Table 8). The results indicated red sorghum, brown *fonio* and white acha provided the best complementation with *A. colei* in terms of weight gain, PER and animal health (Tables 9 and 10). Millet complemented *A. colei* moderately while the cassava–acacia diet resulted in morbidity and mortality of the animals (Table 10).

Rats fed red sorghum incorporating *A. colei* seed flour at 0, 20 and 40% acacia levels were investigated for growth and reproductive performances (Adewusi et al., 2006b). The results showed that weight gain and feed conversion efficiency decreased with increase in *A. colei* incorporation. This was attributed to the quality of acacia protein and not necessarily due to the presence of toxic constituents in the seed. Poor growth, resulting from poor feed conversion efficiency, was also believed to be due to this limiting amino acid. The best complementation, recorded for the *A. colei* – acha diet was attributed to the high level of methionine content of acha (Falade et al., 2008b).

Weanling male and female Wistar rats were fed diets incorporating 0, 20 and 40% *Acacia colei* seed flour, to raise three generations of animals, as shown in Figure 1. Weight gain decreased with increasing levels of acacia incorporation (crude protein content 12.6%) in first generation animals (Table 11). Mating, 13 weeks after weaning, resulted in 80, 60 and 0% pregnancy in female rats, with an average litter size of 5 and 5.5; and survival rate of 83 and 94% by rats fed 0, 20 and 40% acacia diets respectively (Table 11). Increasing the acacia content of the diet resulted in lower body weight gain but increased kidney weight in both male and female rats as when as testis in the male when expressed as a percentage of their body weight (Table 12). Increasing the protein content to 18% reversed the reproductive failure in the 40% acacia group: pregnancy rate was 80, 40 and 71%; mean litter size was 8.5, 12 and 3.8 in rats fed 0, 20 and 40% acacia diets respectively. Growth rate was fastest in the 0% acacia group second-generation rats after the first 64 days. Mating this second generation resulted in 82, 70 and 83% pregnancy over two matings for animals on 0, 20 and 40% acacia diets respectively (Tables 13 & 14). Weights of reproductive and other internal organs were little affected by diet type, indicating that incorporation of acacia into rat diet would not affect reproduction except for the low quality of its protein.

The methionine-deficient acacia protein was also the culprit when the animals were mated and none of the rats on 40% *A. colei* was pregnant.

The protein digestibility amino acid score revealed tryptophan as the limiting amino acid (Table 2). In our subsequent study, supplementation of acacia flour with methionine in a rat assay resulted in tremendous improvement in the acacia protein quality through weight gain, PER and feed conversion efficiency while tryptophan, which was the first limiting amino acid using digestibility corrected amino acid score, did not show any improvement. The complementation study described above in which acacia–acha (known to be rich in methionine) fed rats recorded the best results for all the protein quality assessment parameters did not equally support our in vitro finding. This unresolved problem led to another in vivo study to establish with of the three amino acids (tryptophan, cysteine and methionine is actually the first limiting in *A. colei*). In this study, Wistar strain rats were fed

Acacia colei seed supplemented with three levels of methionine, cysteine and tryptophan (0.1, 0.2 and 0.4%). Supplementation of *A. colei* with tryptophan had no significant effect on both weight gain and protein efficiency ratio (PER), in fact, rats fed 0.1% tryptophan supplemented *A. colei* lost weight (Figure 2). Cysteine supplementation, on the other hand, led to marginal weight gain apart from 0.4% cysteine supplementation which was similar to that of 0.1% methionine supplementation (Figure 3). Methionine supplementation recorded the highest values for both parameters and these parameters increased significantly with increase in methionine content, making methionine the first limiting amino acid (Figure 4).

Harwood (1994) reported the presence of S-carboxyethylcysteine (CEC), a modified sulphur amino acid, at 4.45 mg/g level in *A. colei*. The metabolic function of CEC is not known but it (CEC) is structurally similar to the sulphur amino acids hence the speculation that it may affect the metabolism of the latter. We also investigated the possible effect of the presence of CEC in *A. colei* on its protein metabolism in order to provide evidence to support or negate the speculation. In the study, casein model was used. Casein was supplemented with different levels (0.1, 0.2, 0.4 and 0.8%) of CEC. Our findings showed that the CEC incorporation led to decrease in weight gain with increase in CEC incorporation (Figure 4). PER was also found to decrease with increase in CEC incorporation. This shows that the presence of CEC in *A. colei* could limit its protein utilisation by probably inhibiting methionine and / or cysteine uptake and utilisation in protein biosynthesis.

The safety evaluation of acacia seed–based diets using rat bioassay indicated that the seed is safe for consumption if incorporated into human diets at 25% (Adewusi et al., unpublished paper; Falade et al., 2008b). Our complementation study (Falade et al., 2008b) in which rats were fed for 28 days showed that *A. colei* incorporation into human diets would not likely pose any serious toxicity problems.

The urinary protein level is an indication of the nutritional value of ingested protein in the diet. The result of the urinary chemistry presented in Figure 6 showed that protein content was very low in the urine of rats fed corn starch–acacia–casein and corn starch–acacia diets and highest in those fed sorghum–acacia at the middle of the experiment but towards the end the reverse seemed to hold.

Acid phosphatase concentration, a determinant of kidney damage, was very low in the rats fed starch–acacia and cassava–acacia based rations but moderate in all the other treatments at the mid-point of the study (Figure 7). Acid phosphatase concentration decreased significantly in the urine of rats fed white acha, brown *fonio* and millet but increased in those on sorghum-based ration towards the end of the experiment.

Alkaline phosphatase, another indicator of kidney damage, was highest in the urine of rats fed sorghum–acacia at the middle of the experiment (Figure 8) but not by the end of the experimental period.

Inorganic sulphate in the urine, the major end product of sulphur metabolism in animals, has been used to predict the dietary status of the sulphur amino acids (Lundquist et al. 1980, Adewusi et al. 1993). Inorganic sulphate was highest in the urine of rats fed sorghum–acacia but with little difference with time (Figure 9). Judging by the high level of this metabolite in the urine of rats fed the nutritionally inferior diets (corn starch–acacia alone and cassava–acacia based rations); one would be tempted to infer an adequate dietary supply of the sulphur amino acids. This would however not be consistent with hair loss and the beneficial effects of methionine supplementation (Adewusi et al. 2006 b). An alternative source of the sulphur in the urine of the rats on these diets is the catabolism of S-carboxyethyl cysteine, one of three principal non-protein amino acids in *A. colei* seed (Harwood 1994), followed by the excretion of inorganic sulphate.

The casein–acacia and cassava–acacia diets produced mean levels of lactate dehydrogenase activity in the plasma at least 3–4 times those of the other treatments (Figure10). However, none of the levels recorded are indicative of serious toxicity problems.

Acacia colei human feeding trial

Seed flour *Acacia colei* was incorporated at 0, 15 and 25% (w/w) into the typical diets (Table 15) of rural people of Maradi, Niger Republic and fed to three groups of nine male and nine female volunteers for three weeks.

Anthropometric measurements and indices: The average value of the BMI in the industrialised countries, 25+2.5 (WHO 1986, NHMRC 1991) is higher than those reported here for a poor, sometimes malnourished rural population in the tropics. The increase in BMI and mid-arm circumference for the volunteers on the acacia-incorporated diets provided direct evidence of the beneficial effect of the incorporation of acacia seed flour into human diet. Incorporation of acacia seed flour into the traditional diet of the people of Maradi could lift the BMI value towards the international standard. The weight and BMI of volunteers fed the control diet did not change significantly during the experimental period, while there was a mean increase in these measurement for volunteers on 15 and 25% acacia-incorporated diets (Figure 11). The largest increase in BMI was recorded for the 25% acacia diet, in male volunteers from 20.8 to 21.5 and in the female volunteers from 19.4 to 20.5. Mid-arm circumference measurements followed the same trend (Figure 12), with volunteers on 25% acacia showing the greatest increase by the end of the trial. Analysis of variance showed that overall, across male and female volunteers and the three diets, the incorporation of acacia flour gave statistically significant ($P<0.05$) increases in BMI and mid-arm circumference.

Biochemical analysis of plasma samples (Table 16)

Total protein content: The initial total protein concentration in the plasma, 9.0–9.9 g/dL suggests a general haemoconcentration in the population under study, probably due to dehydration as a reaction to the hot conditions. Average daily maximum temperature was 42°C during the course of the trial. The normal concentration in human plasma is between 6.2 and 8.2 g/dL (Walmsley et al., 1992, Ch. 14). Total protein in the plasma rose by 6–8 % over the course of the trial, except for the male control group where it declined by 4%. This analyte was little affected by the incorporation of acacia into the traditional diet.

Albumin: There was a 41% increase in the plasma albumin concentration in the control male group, while the incorporation of acacia into the diet of the other male groups had little effect on the albumin content. The plasma albumin content in both control and test groups of females increased by 56–100%.

Urea: This by-product of protein metabolism was relatively stable in the plasma of male volunteers irrespective of the diets consumed, while there was a slight increase (14–25%) when acacia was incorporated into the diet of female volunteers.

Bilirubin: The bilirubin concentration, which displayed mean initial values in the range 0.33 to 0.72 mg/dL, dropped in all experimental groups by 10 to 66% over the course of the trial.

Phosphatases and transaminases: Levels of these enzymes in the plasma were highly variable, with no consistent differential response induced by the different diets.

Plasma electrolytes (Table 17): The normal reference range for sodium in the plasma is reported to be 132–144 mmol/L. Mild hyponaetremia with a plasma sodium concentration in the range of 127–131 mmol/L is probably unimportant and self correcting (Walmsley et al., 1992), as was the case in this trial. Potassium is the most abundant electrolyte in the acacia seed (Adewusi et al. 2003) and if fully available could be a cause for concern if large amounts of acacia flour were consumed, as it might lead to possibly fatal hyperkalaemia. The initial plasma sodium concentration in the male and female volunteers showed a mild form of hyponatraemia (mean values generally below 130 mmol/L) but rose during the experimental period to reach 136–149 mmol/L at the end of the study. The initial potassium concentration in both male and female volunteers was in the range of 2.71 to 3.97 mmol/L and this increased by up to 36% to reach a range of 3.32–4.27 mmol/L. The initial calcium concentration ranged between 2.02 and 2.50 mmol/L and remained essentially the same for both male and female volunteers on control and test diets at the end of the study.

Haematological parameters (Table 18): The red blood cell (RBC) counts, which were initially the same in all the male volunteer groups (4.6–4.8 x 10^6 mm^3) were little changed at the end of the study period (4.5–5.0 x 10^6 mm^3). In the female volunteers, the initial RBC count was lower in the 15% acacia group. At the end of the experimental period, the RBC counts in the female groups had changed by less than 10%. It was clear that the different diets had not affected the RBC count over the course of the experiment.

White blood cell count: The baseline white blood cell (WBC) counts varied more than the RBC counts, ranging from 2.8–4.9 x 10^3 mm^3 across both sexes). The counts for male and female groups increased substantially over the course of the trial, for all three diets.

Urinalysis (Table 19)

Total protein: The increase in the total protein content of the urine fluctuated wildly in the course of the study while the plasma concentration, which remained fairly constant, was indicative of an effective renal function. No other urinary parameters in any of the dietary treatments gave cause for concern. The baseline level was low in both male and female volunteers (0.21–0.30 g/dL) but increased during the experimental period to a peak in the second week, falling sharply in the male groups in the third week while remaining fairly stable in the female groups. There were no significant diet-related differences for either males or females.

Acid phosphatase: The initial level of this enzyme was 4.1–6.4 μmol/ml in both male and female volunteer groups. In the male groups, the acid phosphatase level remained fairly constant throughout the study period except for a minor increase in the urine of the control group at the end of the study period. In the female volunteers, the acid phosphatase level increased in the second week of the study but resumed its normal level at the end of the third week.

Alkaline phosphatase: The initial level of this enzyme was 4.3–6.8 μmol/mL in the male groups and 3.7–7.9 μmol/mL in the female. This enzyme remained either stable or varied only slightly throughout the experimental period except for a fairly large drop in the enzyme concentration at the end of the study period, for both sexes and all three diets.

Bilirubin: The bilirubin content varied widely in the control male group throughout the experimental period, remained constant in the first two weeks and decreased during the third week in the 15% acacia group while there was a gradual increase in the level of this enzyme in the volunteers on 25% acacia diet. In the female groups, those on the control diet excreted a fairly constant amount of bilirubin in the first two weeks but levels dropped in the third week. Bilirubin excretion was higher in the second and low in third week for the groups on 15 and 25% acacia diets.

Basal metabolic rate (BMR), daily food energy requirement and calculated total metabolisable energy from the daily food intake

The basal metabolic rates (BMR) of the groups presented in Table 20 have been calculated from the Schofield equations (Schofield et al. 1985) using the age of individuals as supplied and the body weights at the beginning of the study period. The daily food energy requirement was assumed to take into consideration the level of activity of the groups (expressed as a multiple of BMR) and energy needed for growth and lactation. The present results have been calculated on the basis of light/moderate work for men and light work for women. No female volunteer was pregnant, only one female (aged 13), though married, can be considered to be growing actively, while five, seven and six female volunteers in the 0, 15 and 25% acacia groups respectively were breastfeeding children of different ages (3–24 months).

The BMRs for the three male groups were about the same at around 6.7 MJ/day, while those of the female volunteer groups were around 5.3 MJ/day. The food energy requirements of around 11.2 MJ/day for the male and 8.9 MJ/day for the female volunteers were calculated from the BMRs and are at best an approximation as variations in energy requirements can be very large, even in individuals of the same age, sex and body weight, and apparently similar levels of activity. The total food energy calculated from the daily food intake was highest in the 25% acacia-based diet, being 65% in excess of the food energy requirement for the men and over 100% in excess for the women. The 0 and 15% acacia groups also had total food energy intakes well above the requirement for both men and women, but the surplus was less than for the 25% group.

Effects of periods of harvest and storage on chemical composition of acacia seeds

Seeds of acacia species are being trialled for famine food, which means the produce would have to be stored during the good years that hopefully could last for several years. Acacia seed usually has a tough seed coat that protects the endosperm from insect infestation and therefore heavy post-harvest losses. What then becomes the nutritional quality of such stored seeds? This was the question that agitated the mind of Peter Cunningham in Maradi when he invited me to pick up some samples of acacia seeds harvested at different periods. *A. colei* seed harvested from the Danja plantation in 2002, 2006 and 2009 were provided. Part of the *A. colei* seed collected from Maradi in 1995 also became part of the study samples. Other samples included *A. elancantha*, *A. torulosa* harvested in 2002 and 2006, and *A. tumida*.

Moisture content, as expected, decreased with storage within three years in both *A. colei* and *A. torulosa*. Crude protein, crude fibre, ash, fat and carbohydrate by difference were significantly different by years of harvest (Tables 21–23). This is, however, the result of a preliminary investigation and will have to be confirmed further.

The fatty acid profile presented on Table 24 indicated a differences in the samples but not necessary according to years of harvest or storage. Saturated fatty acid content was highest in the 2009 *A. colei* sample, while polyunsaturated fatty acid content was highest in the 1995 *A. colei* sample.

Seeds of *A. colei* harvested at different years were milled with the seed coat, hydrolyzed in vacuo and analysed for amino acid content using the amino acid analyser. The result presented on Table 25 indicated a similar trend for all the *A. colei* samples, however the 2002 sample was consistently lower in all the essential, especially the sulphur, amino acids, the aromatic amino acids and valine as well as the non-essential amino acids. Protein digestibility (Table 22) as well as available lysine content (Table 26) reduced with the years of storage. Water-soluble vitamins also reduced with the years of storage/harvest with ascorbic acid content completely destroyed within a 15-year period (Figure 13). Niacin is however relatively stable.

The results, presented under this section, have posed more questions than provided answers. Could the composition of acacia be affected by environmental factors or could the variation be

due to the existence / creation of hybrid acacia species in Maradi, Niger Republic, as had been observed in other cases (Ng C.H. et al., 2009)

Conclusion

Chemical composition of acacia seeds reported in this review indicated a fair to good protein and fat content, which could serve admirably well as a famine food or as a supplement to normal diet. *Acacia colei* seed as a sole source of protein may induce anaemia and put the immune system under stress as observed in experiments with rats. *Acacia tumida* (obtained from Australia) was more easily processed to remove the seed coat and gave better results for the nutritional parameters than *A. colei.* Nutritional evaluation supported the fact that *A. colei* protein would only support a moderate growth rate with methionine as the first limiting amino acid instead of tryptophan, which was implicated in the digestibility-corrected amino acid score. Brown *fonio* / white acha with a high methionine content was found to be the best cereal to complement *Acacia colei,* followed by red sorghum, while cassava was the poorest. *Acacia colei* as a sole source of protein at less than 13 % could cause reproductive failure as observed in rats. *Acacia colei* seed has been found to be nutritious and safe for human consumption at 25% incorporation. S-carboxyethylcysteine – a non-protein amino acid component of acacia seed – reduced protein utilisation in rats. Storage reduced protein digestibility, extractable protein and the vitamin content of *Acacia colei* and *Acacia torulosa*; it modified their fatty acid composition but did not affect the amino acid profile.

However, the advantages of the acacia species over the conventional arable crops make them ideal crops to combat the menace of hunger in Africa and I wish to recommend these acacia species to the African policy makers.

References

Adegoke O. A., Fadupin G. T., Ketiku A. O. (2006): An Assessment of the Dietary Fibre Intake of Selected Students in the University of Ibadan, Ibadan, Nigeria. *African Journal of Biomedical Research* 9: 157–162

Adewusi, S. R. A., Akindahunsi, A. A., Oke, O. L. (1993): Cassava processing, consumption and human health. In: Roca, W. M., Thro, A. M. (Eds.) *Proceedings of the first International Scientific Meeting of the Cassava Biotechnology Network*, Catagena de Indias, Columbia, S.A. 25-28 August, 1992.

Adewusi S. R. A., Bradbury J. H. (1993): Carotenoids in cassava: a comparison of open column and HPLC methods of analysis. *J. Sci. Food Agric* 62: 375–383

Adewusi S. R. A., Falade O. S. (1996): The effects of cooking on extractable tannin, phytate, sugars and mineral solubility in some improved Nigerian legume seeds. *Food Sci. Technol. Int* 2: 231–240.

Adewusi S. R. A., Falade O. S., Harwood, C.E. (2003): Chemical composition of *Acacia colei* and *Acacia tumida* seeds – potential food sources in the semi-arid tropics *Food Chem* 80: 187-195.

Adewusi S.R.A., Falade, O.S., Oyedapo, O.O., Rinaudo, T. and Harwood, C.E. (2006a): Traditional and *Acacia colei* seed incorporated diets in Maradi, Niger Republic. *Nutrition and Health* 18: 161–177.

Adewusi S.R.A., Falade, Nwoha, P. U., Caxton-Martins, A. E. and Harwood, C.E. (2006b): Reproductive performance of Wistar rats fed *Acacia colei* seed-based diets. *J. Arid Environments 66:* 16–26.

Adewusi S. R. A., Ilori M. O. (1994): Nutritional evaluation of spent grains from sorghum malts and maize grits. *Plant Food Hum*. Nutr 46: 41–51.

Adewusi S. R. A., Osuntogun B. A. (1991): Effects of cooking on Tannin content, Trypsin inhibitor activity and in-vitro Digestibility of some Legume Seeds in Nigeria. *Nig. Food* J 9: 139–145.

Brand J. C., Cherikoff V. (1985): The nutritional composition of Australian Aboriginal food plants of the desert regions. In: Wickens G. E., Goodin, J. R., Field J. V. (Eds) *Plants for Arid Lands, Proceedings of the Kew International Conference on Economic Plants for Arid Lands held in the Jodrell Laboratory, Royal Gardens, Kew, England, 23–27 July 1984*. George Allen and Unwin, London, pp 53–68.

Brand J. C., Cherikoff V., Truswell A. S. (1985): The nutritional composition of Australian Aboriginal bushfoods 3. Seeds and Nuts. *Food Technol. Aust* 37: 275–279.

Brand J. C., Maggiore P. (1992): The nutritional Composition of Australian Acacia Seeds. In: House A. P. N., Harwood, C. E. (Eds.) *Australian Dry-zone Acacia for Human Food.* Canberra Australian Tree Seed Centre, CSIRO Division of forestry, pp. 54 – 67.

CFW (2001): Cereal Food World, Report of the Dietary Fiber Definition Committee to the Board of Directors of the American Association of Cereal Chemists. Submitted January 10, 2001. *CFW* 46: 112–126

Chai W., Liebman M. (2004): Assessment of oxalate absorption from almonds and black beans with and without the use of an extrinsic label. *J Urol.* 172: 953–957

Deis R.E (1999): Dietary Fiber: A Healthy Discussion http://www.foodproductdesign.com/archive/1999/0199de.html

Devitt J. (1992): Acacia: a traditional aboriginal food source in central Australian. In: House A. P. N., Harwood C. E. (Eds) *Australian Dry-zone Acacia for Human Food*. Canberra: Australian Tree seed centre, CSIRO Division of Forestry pp 37–53

Doherty C., Faubion J. M., Rooney L. W. (1982): Semi automated determination of phytate in sorghum and sorghum products. *Cereal Chem.* 59: 373–378

Falade O. S. (2004): Investigation of some Chemical Compounds and their Nutritional values in Seeds of selected Acacia Species. Ph. D. thesis, Obafemi Awolowo University, Ile-Ife, Nigeria.

Falade O. S., Adekunle A. S., Aderogba M. A., Atanda S. O., Harwood C. E., Adewusi S. R. A. (2008a): Physiochemical properties, total phenol and tocopherol of some acacia seed oils. *J. Sci. Food Agric* 88: 263–268.

Falade O. S., Adewusi S. R. A., Akindahunsi A. A., Harwood C. E. (2008b): Complementation between protein of *Acacia colei* seed and some carbohydrate sources in West Africa. In: Adebooye O. C., Taiwo K. A., Fatufe A. A. (Eds) *Food, Health and Environmental Issues in Developing Countries: The Nigerian Situation*. Cuvillier Verlagöttingen, Germany, pp 408–425.

Falade O. S., Owoyomi O., Harwood C. E., Adewusi S. R. A. (2005): Chemical Composition and Starch Hydrolysis of *Acacia colei* and *Acacia tumida* Seeds. *Cereal Chem.* 82: 479–484

FAO / US Department of Health, Education and Welfare (1968): *Food Composition Table for use in Africa.* Bethesda, Md. / Rome, Italy

FAO/WHO (1991): *Protein Quality Evaluation. Report of the Joint FAO/WHO Expert Consultation.* Bethesda, Md., USA 4-8 December, 1991.

Gatel F., Grosjean F. (1990): Composition and nutritive value of pea for pigs: a review of European results. *Livestock Production Science* 26: 155 – 175

Harwood C. E. (1994) Human Food Potential of the seeds of some Australian Dry-zone acacia species. *J. Arid Environ* 27: 27–35

Harwood, C.E., Rinaudo, T. and Adewusi, S (1999). Developing Australian acacias as a human food source in the Sahel. *Unasylva* 196; 57–64.

Jacobberger J . W. (2001) Stoichiometry of immunocytochemical staining reactions. *Methods Cell Biol* 63: 271–98

Knuckles B. E., Kuzmicky D. D., Gumbmann M. R., Betschart, A. A. (1989) Effect of myo-inositol phosphate esters on in vitro digestion of protein. *J. Food. Sci* 54:1348–1350

Lundquist, P., Martensson, J., Sorbo, B., Ohman, S. (1980). Turbidimetry of inorganic sulfate, ester sulfate, and total sulfur in urine. *Clin. Chem.* 26:1178-1181.

Mayer K. A., Kushi L. H., Jacobs D. R., Slavin J., Sellers T. A., Folsom A.R. (2000) Carbohydrates, fibre and incident type 2 diabetes in older women. *Am. J. Clin. Nutr*. 71: 921–930

McHarry J., Scott F., Green J. (2002): Towards Global Food Security: Fighting against hunger. Towards Earth Summit 2002, Social Briefing #4 http://www.earthsummit2002.org/es/issues/foodsecurity/foodsecurity.rtf

Murray D. R., McGee C. M. (1986): *Seed protein content of Australian species of acacia*. Proceedings of Linnaean Society of New South Wales, 108: 187–190

Ng, C.-H.; Lee, S.-L.; Ng, K. K.-S.; Muhammad, N. and Ratnam, W. (2009): Mating system and seed variation of acacia hybrid (*A. mangium* × *A. auriculiformis*). *J. Genet*. 88, 25–31.

NHMRC (1987): National Health and Medicinal Research Council. *Recommended dietary intakes for use in Australia.* Australian Government Publishing Service, G.P.O. Box 84, Canberra, ACT 2601

NHMRC (1991): National Health and Medical Research Concil. *Recommended Dietary intakes for use in Australia.* Australian Government Publishing Service, G.P.O. Box 84, Canberra ACT2601

Ononiwu N. (2007): Nigeria: Combating desertification with the "Green Wall Sahara Initiative (GWSI). In The Tide http://desertification.wordpress.com/2007/08/09/nigeria-combating-desertification-with-the-%E2%80%9Cgreen-wall-sahara-initiative-gwsi%E2%80%9D-google-alert-the-tide/

Price M. L., Southan S., Fenwick C. R. (1989): The effect of saponins on iron and zinc availability. In: Southgate D., Johnson I., Fenwick C. R. (Eds) *Nutrient availability: Chemical and biological aspects.* The Royal Society of Chemistry, Cambridge, England, pp 155–157

Radford T., Vidal J. (2005) One in six countries facing food shortage; in *The Guardian*; Thursday June 30,

Rinaudo T., Patel P., Thomson L. A. J. (2002): Potential of Australian acacias in combating hunger in semi-arid lands. *Conservation Science W. Aust*. 4: 161–169

Santamaria P., Elia A.., Serio F., Todaro E. (1999): A survey of nitrate and oxalate content in fresh vegetables. *J. Sci. Food Agric* 79: 1882–1888

Schofield, W.N., Schofield, C. and James, W.P.T. 1985 Basal metabolic rate - review and prediction, together with an annotated bibliography of source materials. *Hum Nutr Clin Nutr* 39C (Suppl 1) 1–96.

The Tide on Line (2007): citing a statement by the President, Nigerian Conservation Foundation (NCF), Chief

Philip Asiodu http://www.thetidenews.com/article.aspx?qrDate=01/30/2007&qrTitle=Nigeria%20risks%20 extinction%20of%20forest%20by%202010%20%E2%80%93%20Asiodu&qrColumn=BUSINESS

UNECA (2008): United Nations Economic Commission for Africa, *Africa Review Report on Drought and Desertification*. Addis Ababa, Ethiopia www.uneca.org.

Van Crowder L., Lindley W. I., Bruening T. H., Doron N. (1998): *Agricultural Education for Sustainable Rural Development: Challenges for Developing Countries in the 21st Century*; Extension, Education and Communication Service (SDRE); FAO Research; Rome, Italy

Walmsley, R.N., Watkinson, L.R. and Koay, E.S.C. (1992) *Cases in Chemical Pathology - a diagnostic approach.* Third edition. Singapore, World Scientific. 451 pp.

WB / ISDR (2007): *The World Bank and United Nations International Strategy for Disaster Reduction (ISDR).* Report on the Status of Disaster Risk Reduction in the Sub-Saharan Africa (SSA) Region

WWI (1998): *A guide to the global environment*; World Resources Institute, Washington DC, USA

Table 1: Chemical composition of acacia seeds (% dry weight)*

	A. colei **sieved**	***A. tumida*** **(I)**	***A. tumida*** **(II)**	***A. tumida*** **(III)**
Moisture	6.4 ± 0.3 ^{b}	7.2 ± 0.1^{a}	7.8 ± 0.4^{a}	7.4 ± 0.5^{a}
Crude protein	22.3 ± 0.2 ^{c}	22.6 ± 0.4$^{a\ c}$	20.6 ± 0.4^{c}	23.0 ± 0.6^{a}
True protein				
Colorimetric method	17.5 ± 0.3 ^{a}	12.4 ± 1.2^{b}	11.5 ± 0.9^{b}	12.6 ± 0.7^{b}
True protein: ppt at				
pH 8	4.8 ± 0.1 ^{a}	5.1 ± 0.6^{a}	4.9 ± 0.2^{a}	5.2 ± 0.5^{a}
pH10	13.8 ± 0.2	7.7 ± 0.5^{c}	7.0 ± 0.1^{c}	8.1 ± 0.9^{b}
Ether extract	11.9 ± 0.5 ^{a}	7.8 ± 0.1^{c}	10.5 ± 0.5^{b}	7.7 ± 0.06^{c}
IDF**	23.7 ± 1.0 ^{a}	26.9 ± 2.1^{b}	26.3 ± 0.7^{b}	26.1 ± 0.5^{b}
SDF***	5.4 ± 0.9 ^{a}	5.8 ± 0.6^{a}	2.2 ± 0.4^{b}	3.2 ± 0.4^{c}
TDF	29.5 ± 1.6 ^{a}	32.7 ± 1.3^{be}	28.5 ± 0.8^{a}	29.2 ± 0.3^{a}
Tannins (mg/g)	86.7 ± 1.2 ^{a}	80.3 ± 6.4^{b}	83.0 ± 7.6^{b}	66.0 ± 5.7^{c}
Trypsin Inhibitor (TIU/g)	23	24.5	19	18
Oxalate (g / 100 g)	2.4 ± 0.2^{a}	2.3 ± 0.1^{a}	2.2 ± 0.2^{a}	2.6 ± 0.2^{a}

Source: Falade et al., (2005)

Values in the same row with the same superscripts are not significantly different at the 5% probability level.
* Mean and Standard deviation of 3–5 replicates. ** IDF = Insoluble Dietary Fibre; **SDF = Soluble Dietary Fibre; TDF = as is (Total Dietary Fibre)
A. tumida (I) = Broome. 18653, *A. tumida* (II) = Pt Hedland. 17964 and *A. tumida* (III) = Tanami. 18646.
Tannin and Phytate = mean ± SD of three determinations; Oxalate = mean ± SD of 4 replicates.

Table 2: Amino acid composition of *A. colei* and *A. tumida* seeds

Amino acids	Ref[c]	*A. colei* whole	*A. colei* water-processed	*A. colei* sieved	*A. tumida*
Asp		19.0 (61)	23.1	22.5	21.9
Thr	34	8.3	11.8 (79)	9.1 (63)[d]	8.0 (80)
Ser		12.5	17.3	13.6	12.3
Glu		30.5	40.1	33.4	30.5
Pro		8.9	13.3	10.2	9.9
Gly		11.8	13.2	11.6	12.1
Ala		9.3	12.7	10.3	9.0
Val	35	11.6	14.9 (97)	12.7 (85)	13.4 (130)
Met		3.2	4.3	3.5	2.6
Ile	28	8.8 (78)	11.9 (97)	9.7 (81)	8.4 (102)
Leu	66	17.2 (65)	23.3 (81)	18.6 (66)	16.1 (83)
Tyr		8.4	11.0	8.5	7.9
Phe		9.9	12.7	10.0	8.9
Lys	58	14.3 (61)	16.0 (63)	16.5 (67)	15.2 (89)
His	19	7.6 (99)	7.9 (95)	8.0 (99)	7.1 (127)
NH3		4.4	5.8	4.5	4.3
Arg		15.1	19.1	17.4	15.2
Cys & Cy		2.9	3.3	3.1	2.8
Trp	11	2.2 (50)	2.7 (56)	2.5 (53)	1.9 (59)
Met + Cys	25	6.1 (61)	7.6 (70)	6.6 (62)	5.4 (73)
Phe + Tyr	63	18.3 (72)	23.7 (86)	18.5 (69)	16.8 (91)
Nitrogen		37.4	48.9	39.5	32.0
E.A.A. as % of total including His[e]		45.6	45.3	45.3	44.5
% True digestibility		58	70	58	68

Source: Adewusi et al., (2003)

[a] Protein digestibility-corrected amino acid score was calculated using the true digestibility of acacia seeds in a 28-day rat bioassay (to be reported elsewhere) as outlined by FAO/WHO, 1991.

[b] All values in parentheses are calculated by first converting the amino acid values to g/kg protein and expressed as % of reference value.

[c] Reference—the amino acid requirement for pre-school children (2–5 years old) as expressed in g/100g protein (FAO/WHO, 1985)

[d] Based on a 58.2% true digestibility for the whole acacia seed, but recent bioassay gave values of true digestibility as low as 19% (reported elsewhere).

[e] E.A.A.– essential amino acids.

Table 3: Chemical composition of carbohydrate sources used in the study and *Acacia colei* seed flour

Foodstuff	Crude protein	Ash	Crude lipid	Crude fibre	Dietary fibre	*In vitro* protein digestibility	Total sugar	Phytate	Tannin
	%						mg/g		
White acha 1	8.0	0.3	1.5	0.3	1.7	65	69	0.7	3.8
White acha 2	9.0	0.3	1.1	0.2	0.6	58	58	0.3	3.3
Brown *fonio*	7.0	0.4	2.1	0.2	0.5	92	62	0.7	5.0
Millet	9.5	2.4	4.9	0.7	9.5	183	73	1.3	5.8
Red sorghum	8.7	1.9	3.7	1.1	9.6	138	64	1.3	15.4
White sorghum	9.5	1.7	3.4	1.1	9.8	125	67	1.1	1.2
Cassava	1.8	2.0	1.8	0.5	5.1	355	62	0.2	1.3
Acacia colai flour sieved	21.4	3.5	12.1	-	29.1	137	-	0.09	86.7
Maximum standard errors	0.5	0.2	0.2	0.1		18	3.8	0.1	1.2

Source: Falade et al., (2008b)

Table 4: Chemical properties of the oils

Characteristics	Groundnut oil	*A. colei* seed oil	*A. tumida* seed oil
Ether extract*	53.9 ± 1.3^{c}	12.6 ± 0.5^{b}	10.2 ± 0.4^{a}
Iodine value**	109.3 ± 8.3^{a}	154.9 ± 4.1^{b}	178.3 ± 6.7^{c}
Saponification value***	198.0 ± 14.6^{a}	201.7 ± 10.0^{a}	202.2 ± 4.4^{a}
Unsaponifiable matter *	0.6 ± 0.2^{ab}	0.5 ± 0.1^{a}	1.0 ± 0.2^{b}
Acid value**	0.8 ± 0.1^{a}	15.1 ± 1.2^{c}	10.2 ± 0.4^{b}
FFA (as oleic acid) *	0.4 ± 0.0^{a}	7.6 ± 0.6^{c}	5.1 ± 0.2^{b}
Peroxide value****	10.9 ± 1.3^{b}	11.7 ± 1.4^{b}	6.2 ± 1.2^{a}
Total phenols*****	30.3 ± 1.4^{a}	101.2 ± 6.3^{b}	117.3 ± 3.6^{c}
Total tocopherol*****	43.4 ± 0.3^{a}	106.1 ± 5.1^{b}	143.6 ± 6.3^{c}

Source: Falade et al., (2008a)

Values are means of triplicate determination ± standard deviation of mean.

Values in the same row with the same superscripts are not significantly different at the 5 % probability level.

*Values are expressed in %

** Values are expressed in g iodine/100 g oil

*** Values are expressed in mg KOH/g oil

**** Values are expressed in meq peroxide/kg

***** Values are expressed in mg/kg

Table 5: Mineral element content (mg / 100 g) of carbohydrate sources and *Acacia colei* flour

	Cassava flour	Millet	Brown *fonia*	White acha 1	White acha 2	Red sorghum	White sorghum	*A. colei* sieved flour	*A. tumida*
Mg	6.1	17.6	7.4	5.3	9.2	16.4	16.5	290	261
Fe	54.5	69.4	175.4	71.4	383.7	111.0	49.5	31	54.4
Mo	842.1	1175.7	662.0	583.9	340.0	1435.1	1298.7	-	-
Al	10.7	23.2	35.9	16.6	16.7	32.8	15.7	6.0	-
Ca	817.9	197.2	300.2	239.7	248.9	95.7	150.6	274	168.4
Na	98.0	22.8	60.1	45.8	49.2	36.0	24.5	7.0	ND
K	5987	3838	521	439	271	2950	3180	934	914
Zn	6.5	33.0	19.4	19.2	22.6	22.2	26.0	3.0	2.25
Ph	0.4	0.3	0.3	0.6	0.6	0.3	0.2	0.1	0.0
Cd	0.06	0.1	0.04	0.04	0.04	0.04	0.04	Nd	ND
Ni	3.4	1.3	9.2	1.0	26.5	1.4	1.3	-	-
Cu	4.5	4.1	1.8	3.5	4.4	3.2	2.9	0.6	35.8
Sr	4.5	1.2	1.9	1.6	1.7	0.7	1.0	-	-
B	4.2	2.2	2.2	1.8	2.1	3.3	2.3	-	-
Co	0.4	1.2	4.3	1.5	1.5	1.3	1.9	-	-
Ba	4.0	2.4	12.8	1.7	1.9	1.5	1.8	-	-

Source: Falade et al., (2008b)

A. tumida values are from Adewusi et al., (2003)

Table 6: Feed intake, weight gain, protein efficiency ratio (PER) and net protein retention (NPR) over 28 days for the seven experimental diets. Means ± standard errors shown

Diet	Feed intake	Weight gain	PER	NPR
Protein-free	118.5 ± 1.9	-28.3 ± 1.0	-	-
Casein control	134.1 ± 5.9	7.2 ± 0.3	0.54 ± 0.06	2.5 ± 0.12
A. colei (unprocessed, with seed coat)	244.2 ± 5.4	35.1 ± 3.0	1.43 ± 0.07	2.6 ± 0.10
A. colei (water processed*)	240.0 ± 2.0	21.9 ± 0.9	0.91 ± 0.03	2.1 ± 0.04
A. colei (processed*, + methionine)	238.2 ± 13.1	40.0 ± 4.4	1.66 ± 0.11	2.9 ± 0.08
A. tumida	287.3 ± 1.6	41.2 ± 1.4	1.43 ± 0.05	2.4 ± 0.04
A. tumida + methionine	383.7 ± 6.6	80.9 ± 4.0	2.10 ± 0.07	2.8 ± 0.04

Source: Adewusi et al., unpublished results

Table 7: Feed intake, weight gain, feed and protein consumed, protein efficiency ratio and net protein retention for rats fed 0, 20 and 40% *Acacia colei*-supplemented diets for 13 weeks, ± standard errors

	Level of *A. colei* supplementation		
Parameters	**0 %**	**20%**	**40%**
(a) After 4 weeks			
Weight gain (g)	81.2 ± 3.3	69.5 ± 1.7	44.6 ± 1.6
Feed consumed (g)	283 ± 6.0	290 ± 5.8	255 ± 8.9
Protein consumed (g)	42.4 ± 0.9	43.2 ± 0.9	37.3 ± 1.3
Protein efficiency ratio	1.9 ± 0.07	1.6 ± 0.13	1.2 ± 0.02
Net protein retention	2.6 ± 0.04	2.2 ± 0.02	1.9 ± 0.02
(b) After 13 weeks			
Weight gain (g)	143 ± 6.3	162 ± 6.3	113 ± 2.7
Feed consumed (g)	958 ± 13	1032 ± 12	944 ± 11
Protein consumed (g)	144 ± 2.0	154 ± 1.8	141 ± 2.3
Protein efficiency ratio	1.0 ± 0.05	1.1 ± 0.05	0.8 ± 0.02

Source: Adewusi et al., unpublished results

Table 8: Feed composition of rats fed *Acacia colei* seed flour and different carbohydrate sources

	Diets							
Diet components (% by weight)	**Protein free diet**	**Casein + acacia**	**Acacia alone**	**Cassava + acacia**	**White acha[1] + acacia**	**Brown *fonio* +acacia**	**Millet +acacia**	**Red sorghum + acacia**
Corn starch	66.2	43.96	38.0	-	16.35	11.66	20.56	17.17
Sucrose	10.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Casein	-	5.1	-	-	-	-	-	-
Acacia	-	24.0	40.0	36.92	24.0	24.0	24.0	24.0
White acha	-	-	-	-	33.3	-	-	-
Cassava	-	-	-	41.1	-	-	-	-
Brown *fonio*	-	-	-	-	-	38.3	-	-
Millet	-	-	-	-	-	-	30.2	-
Red sorghum	-	-	-	-	-	-	-	33.5
Dietary fibre	10.0	2.54	-	0.30	2.45	2.46	2.32	2.17
Oil	8.8	4.40	2.0	1.70	3.90	3.58	2.92	3.16
Mineral mix	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Vitamin mix	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

[1]Acha: *Digitaria exilis*

Source: Source: Falade et al., (2008b)

Table 9: Feed intake, weight gain, protein efficiency ratio (PER), net protein retention (NPR), true digestibility (TD) over 28 days, and number of rats surviving (out of 6) for the different bioassay diets. Standard errors are shown.

Diet	Feed intake (g)	Weight gain/loss (g)	PER	NPR	TD	Number surviving
Protein free diet	118.5 ± 1.9	-28.3 ± 1.0	-	-	-	2
Starch / casein / acacia	124 ± 19.4	8.1 ± 3.2	0.6 ± 0.2	2.9 ± 0.4	56.8 ± 5.2	4
Starch / acacia	95 ± 14.6	-2.5 ± 3.8	-0.3 ± 0.3	2.7 ± 0.4	55.1 ± 6.8	3
Cassava / acacia	122 ± 22.0	-2.5 ± 2.5	-0.4 ± 0.1	2.1 ± 0.4	76.0 ± 6.4	2
White acha / acacia	196 ± 33.7	25.4 ± 4.2	1.3 ± 0.2	3.0 ± 0.4	55.1 ± 2.1	6
Brown *fonio* / acacia	204 ± 35.3	28.7 ± 4.3	1.4 ± 0.2	3.0 ± 0.3	56.7 ± 2.7	6
Millet / acacia	131 ± 15.8	6.6 ± 1.0	0.5 ± 0.1	3.0 ± 0.2	51.7 ± 1.0	5
Red sorghum / acacia	166 ± 1.1	18.0 ± 1.9	1.1 ± 0.1	3.1 ± 0.3	52.8 ± 1.5	5

Source: Falade et al., (2008b)

Table 10: Morbidity and physiological parameters of rats fed complemented acacia diets

Diet	Sluggish movement	Eye infection	Hair loss	No of death
Protein free diet	2	2	2	2
Starch / casein / acacia	2	2	1	2
Starch / acacia	2	5	-	3
Cassava / acacia	4	2	-	4
White acha / acacia	-	-	1	-
Brown *fonio* / acacia	-	1	2	-
Millet / acacia	1	-	1	1
Red sorghum / acacia	1	1	1	1

Source: Falade et al., (2008b)

Table 11: Mean food intake, average weight gain, pregnancy and reproductive performance of F_0 rats fed 0, 20 and 40% (w/w) acacia incorporated diets for 15 weeks.* All diets contained 12.6% crude protein content.

Acacia incorporation (%)	0	20	40
Female rats			
Number of rats	10	10	10
Food Consumption (g/kg bw)	5506 ± 329	5766 ± 503	6698 ± 1142 *
Feed intake (g/rat)	985 ± 23.9	914 ± 26.2 *	780 ± 28.1 **
Weight gain (g)	96 ± 6.1	76 ± 9.6 *	36 ± 12.8 **
Feed conversion efficiency [a]	10.3 ± 0.3	12.0 ± 0.3 *	21.7 ± 0.8 **
Weight range before mating (g)	170 - 200	145 - 185	90 - 150
Number falling pregnant	8	6	0
Number of offspring/rat	5.0 ± 1.1	5.5 ± 0.8	0.00 *
Male rats			
Number of rats	5	5	5
Feed consumption (g/kg bw)	5193 ± 364	6041 ± 865	6417 ± 989 *
Feed intake (g/rat)	1195 ± 22	1081 ± 21 *	772 ± 19 **
Weight gain (g)	158 ± 5	109 ± 14 *	52 ± 12 *
Feed conversion efficiency [a]	7.6 ± 0.1	9.9 ± 0.2 *	14.8 ± 0.4 **
Weight range before mating (g)	210 - 255		155 - 210

* Values with different asterisks within the same row are significantly different from each other and the control at $p > 0.05$

[a] (g feed / g weight gain)

Source: Adewusi et al., (2006a)

Table 12: Organ weights of F_0 generation rats, rats fed 0, 20 and 40 % (w/w) acacia incorporated diets after 24 weeks.*

Levels of acacia incorporation (%)	0	20	40
Female animals (n=3)			
Body weight (g)	163 ± 3.4	173 ± 7.8	135 ± 1.8 *
Liver (g)	5.7 ± 0.2	5.5 ± 0.1	4.2 ± 0.1 *
(% of body weight)	3.5 ± 0.1	3.2 ± 0.1	3.1 ± 0.04
Kidney (g)	0.49 ± 0.01	0.52 ± 0.00 *	0.41 ± 0.02 **
(% of body weight)	0.3 ± 0.01	0.3 ± 0.00	0.3 ± 0.02
Heart (g)	0.44 ± 0.00	0.37 ± 0.01	0.39 ± 0.02
(% of body weight)	0.3 ± 0.00	0.2 ± 0.04	0.3 ± 0.01
Male animals (n=3)			
Body weight (g)	283 ± 7.8	178 ± 14.6 *	118 ± 3.4 **
Liver (g)	8.1 ± 0.3	3.9 ± 0.3 *	3.7 ± 0.1 *
(% of body weight)	2.9 ± 0.0	2.2 ± 0.2 *	3.1 ± 0.1
Kidney (g)	0.66 ± 0.01	0.38 ± 0.03 *	0.37 ± 0.01 *
(% of body weight)	0.23 ± 0.01	0.21 ± 0.01	0.31 ± 0.01 *
Heart (g)	0.62 ± 0.01	0.36 ± 0.03 *	0.37 ± 0.00 *
(% of body weight)	0.22 ± 0.02	0.20 ± 0.01	0.31 ± 0.00*
Testis (g)	1.4 ± 0.02	1.2 ± 0.02*	1.1 ± 0.02 *
(% of body weight)	0.47 ± 0.01	0.63 ± 0.01*	0.93 ± 0.02 **

* Values with different asterisks within the same row are significantly different from each other and the control at $p > 0.05$

Source: Adewusi et al., (2006a)

Table 13: Reproductive performance of first generation (F_0) female rats fed improved 0, 20 and 40% (w/w) acacia-incorporated diets for nine weeks.

Level of acacia incorporation (%)	0	20	40
Number of rats	5	5	7
Average weight at mating (g)	207 ± 10.5	194 ± 7.3 *	156 ± 9**
Number falling pregnant	4	2	5
Litter size/rat	8.5 ± 0.9	12 ± 1 *	3.8 ± 0.2 **
Weight at birth (g/pup)	5.8 ± 0.4	6.0 ± 0.6	6.8 ± 0.9
Weight at 7 days (g/pup)	9.6 ± 1.0	10.0 ± 1.1	16.4 ± 1.5 *
Survival rate at weaning (%)	97	83	95

* Values with different asterisks within the same row are significantly different from each other and the control at p > 0.05

Source: Adewusi et al., (2006a)

Table 14: Reproductive performance of female rats following the second mating of second generation (F_1) rats

Level of acacia incorporation (%)	0	20	40
Number of rats	5	4	6
Average weight at mating (g)	230 ± 5.5	210 ± 10 *	189 ± 4.5**
Number falling pregnant	3	4	4
Average litter size/rat	4.3 ± 0.4	7.5 ± 0.6 *	7.8 ± 1.0 *
Weight at birth (g/pup)	5.2 ± 0.8	4.3 ± 0.5	3.7 ± 0.7 *

* Values with different asterisks within the same row are significantly different from each other and the control at p > 0.05

Source: Adewusi et al., (2006a)

Table 15: The proximate composition of traditional and acacia-incorporated foods (% dry weight basis). Means ± standard errors shown.

Food type and % acacia	Crude protein %	Ether extract %	Ash %	Dietary fibre %	Carbohydrate %[1]
Burabusko					
0	6.5 ± 0.3	5.0 ± 0.4	3.7 ± 0.3	9.5	75.3
15	7.4 ± 0.5	5.4 ± 0.4	4.8 ± 0.4	12.5	69.9
25	9.4 ± 0.3	6.5 ± 0.3	4.0 ± 0.6	14.4	65.7
Tuwo-Millet					
0	9.3 ± 0.2	5.1 ± 1.0	5.4 ± 1.0	9.5	70.7
15	10.7 ± 0.1	5.5 ± 0.5	4.7 ± 0.2	12.5	66.6
25	12.7 ± 0.4	4.1 ± 1.0	4.3 ± 0.5	14.4	64.5
Fura					
0	9.1 ± 0.4	1.3 ± 0.1	1.6 ± 0.2	9.5	78.5
15	9.7 ± 0.6	2.2 ± 0.4	1.8 ± 0.2	12.5	73.8
25	11.5 ± 0.7	2.4 ± 0.2	2.3 ± 0.2	14.4	69.4
Chin-Chin					
0	8.4 ± 0.0	13.9 ± 0.5	1.6 ± 0.1	5.2	67.8
15	9.1 ± 0.4	16.1 ± 0.7	2.4 ± 0.1	8.8	61.4
25	10.8 ± 0.2	12.3 ± 1.7	2.3 ± 0.0	11.2	64.3
Danwake Millet					
0	21.1 ± 0.3	1.8 ± 0.1	3.4 ± 0.1	9.5	64.2
15	23.0 ± 0.6	2.4 ± 0.3	5.1 ± 0.2	12.5	57.5
25	19.0 ± 0.8	4.5 ± 0.3	5.2 ± 0.4	14.4	56.7
Masulali					
0	9.0 ± 0.4	8.0 ± 0.5	4.5 ± 0.1	9.9	67.6
15	9.6 ± 0.3	9.0 ± 0.7	4.9 ± 0.1	12.9	63.5
25	10.0 ± 0.6	13.0 ± 1.4	5.5 ± 0.1	14.8	56.1
Kunu/Koko					
0	11.0 ± 0.6	4.6 ± 0.1	2.2 ± 0.1	9.5	72.7
15	15.4 ± 0.4	5.2 ± 0.1	3.3 ± 0.1	12.5	63.6
25	15.1 ± 0.1	5.4 ± 0.2	3.3 ± 0.2	14.4	61.8
Massa-Damia					
0	5.0 ± 0.6	35 ± 1.7	2.5 ± 0.4	8.6	48.9
15	6.6 ± 0.4	27 ± 0.9	3.3 ± 0.2	11.7	51.4
25	7.2 ± 0.7	25 ± 1.0	3.3 ± 0.2	13.7	50.8
Tuwo - sorghum					
0	11.0 ± 0.0	4.5	7.7 ± 0.3	9.6	67.2
15	11.5 ± 0.2	3.5	5.0 ± 0.5	12.5	67.5
25	12.8 ± 0.1	3.7	3.8 ± 0.2	14.5	65.2

[1]calculated by difference

Source: Adewusi et al., (2006b)

Table 16: Biochemical analysis of the plasma of male and female human volunteers fed 0, 15 and 25% acacia-incorporated diets*

			Phosphatases		Transaminases				
Sex and level of acacia incorporation	Sampling Perio	Total Protein mg/ml	Acid µmol/ ml	Alkaline µmol/ml	GOT SF units/ml	GPT SF units/ml	Albumin g/dl	Bilirubin mg/dl	Urea g/l
Male 0 %	Initial	9.9 + 0.1	16.2 + 0.8	37.3 + 1.4	56.0 + 1.5	49.4 + 0.4	3.2 + 0.2	0.5 + 0.03	0.18 + 0.01
0%	Final	9.5 + 0.1	30.9 + 1.3	39.9 + 1.7	49.6 + 1.6	54.9 + 1.6	4.5 + 0.1	0.26+ 0.01	0.16 + 0.01
15%	Initial	9.3 + 0.1	24.6 + 1.6	97.3 + 4.7	49.5 + 2.3	46.1 + 1.7	5.1 + 0.1	0.37 + 0.01	0.22 + 0.01
15%	Final	10.0 + 0.1	23.7 + 0.7	33.2 + 0.8	35.8 + 1.2	50.2 + 1.0	4.8 + 0.1	0.39 + 0.01	0.21 + 0.01
25%	Initial	8.8 + 0.1	29.7 + 1.3	69.1 + 1.8	39.9 + 1.6	66.0 + 3.1	5.1 + 0.1	0.33 + 0.01	0.21 + 0.01
25%	Final	9.5 + 0.1	27.3 + 1.2	36.6 + 1.6	48.3 + 2.4	46.3 + 2.4	4.7 + 0.1	0.26 + 0.01	0.21 + 0.01
Female 0%	Initial	9.0 + 0.1	14.4 + 0.4	43.6 + 1.5	38.9 + 1.0	30.3 + 1.3	2.7 + 0.1	0.51 + 0.01	0.17 + 0.01
0%	Final	9.6 + 0.1	19.4 + 0.5	40.0 + 0.8	62.8 + 1.3	47.0 + 0.2	5.4 + 0.1	0.46 + 0.01	0.15 + 0.01
15%	Initial	9.5 + 0.0	28.1 + 1.3	49.9 + 1.5	45.7 + 1.5	30.6 + 0.1	3.6 + 0.1	0.74 + 0.01	0.16 + 0.01
15%	Final	9.8 + 0.1	19.4 + 0.3	33.4 + 1.0	68.4 + 1.0	31.8 + 0.2	5.6 + 0.1	0.25 + 0.01	0.20 + 0.01
25%	Initial	9.5 + 0.1	46.4 + 1.7	60.2 + 2.0	53.1 + 0.3	36.9 + 0.2	3.6 + 0.1	0.77 + 0.01	0.21 + 0.01
25%	Final	10.1 + 0.1	26.6 + 0.9	63.1 + 1.4	59.1 + 1.1	28.2 + 0.3	5.7 + 0.0	0.47 + 0.01	0.24 + 0.01

*Means of 18 – 36 samples per treatment, ± standard errors

Source: Adewusi et al., in press

Table 17: Analysis of plasma electrolyte of male and female human volunteers fed 0, 15 and 25% acacia-incorporated diets*

Level of acacia	Sampling period	Sodium mmol / L	Potassium mmol / L	Calcium mmol / L
Male				
0%	Initial	112.1 + 12.1	3.63 + 0.09	2.06 + 0.04
	Final	142.7 + 2.7	3.32 + 0.03	2.16 + 0.08
15%	Initial	127.7 + 4.7	2.74 + 0.13	2.15 + 0.05
	Final	139.4 + 2.5	3.43 + 0.03	2.11 + 0.02
25%	Initial	128.7 + 2.1	2.71 + 0.05	2.50 + 0.06
	Final	136.3 + 3.6	3.68 + 0.06	2.16 + 0.02
Female				
0%	Initial	127.2 + 1.4	3.71 + 0.11	2.02 + 0.03
	Final	144.7 + 2.1	4.26 + 0.08	2.16 + 0.05
15%	Initial	126.5 + 1.1	3.52 + 0.07	2.25 + 0.06
	Final	149.3 + 1.0	4.27 + 0.08	2.20 + 0.04
25%	Initial	133.6 + 1.3	3.97 + 0.06	2.26 + 0.05
	Final	144.7 + 0.59	3.84 + 0.12	2.18 + 0.04

*Mean of 18 samples per treatment, ± standard error.

Source: Adewusi et al., in press

Table 18: Haematological parameters of male and female volunteers fed 0, 15 and 25% acacia-incorporated diets*.

Sampling period / level of acacia	RBC x 10^6 mm^{-3}	WBC x 10^3 mm^{-3}	Neutrophil	Basophil	Eosinophil	Lymphocyte	Monocyte
Male 0%							
Initial	4.8 ± 0.3	4.2 ± 0.7	50.0 ± 10.7	0.0	0.9 ± 0.5	47.1 ± 10.8	2.0 ± 0.7
Final	4.9 ± 0.3	5.5 ± 0.6	47.4 ± 3.8	0.0	6.1 ± 1.7	47.6 ± 3.9	0.4 ± 0.3
Male 15%							
Initial	4.6 ± 0.3	4.9 ± 0.8	30.4 ± 8.3	0.0	0.3 ± 0.2	62.4 ± 8.5	3.8 ± 2.1
Final	4.5 ± 0.2	6.7 ± 0.4	5.4 ± 2.3	0.0	0.3 ± 0.6	39.9 ± 2.3	0.7 ± 0.5
Male 25%							
Initial	4.7 ± 0.3	3.0 ± 0.32	28.3 ± 6.5	0.0	8.1 ± 4.6	59.8 ± 6.1	5.1 ± 3.4
Final	5.0 ± 0.3	5.5 ± 0.6	44.6 ± 1.8	0.0	5.9 ± 1.5	49.6 ± 1.7	0.0
Female 0%							
Initial	4.5 ± 0.2	2.8 ± 0.5	14.9 ± 4.3	0.0	14.3 ± 4.8	70.9 ± 3.8	0.0
Final	4.1 ± 0.2	56.4 ± 3.4	56.4 ± 3.4	0.0	5.5 ± 1.0	37.8 ± 3.1	0.5 ± 0.3
Female 15%							
Initial	3.7 ± 0.2	2.9 ± 0.2	48.8 ± 5.1	0.0	0.1 ± 0.1	50.6 ± 4.9	0.5 ± 0.2
Final	3.5 ± 0.2	4.9 ± 0.32	42.8 ± 3.6	0.0	2.4 ± 0.7	55.5 ± 3.8	0.7 ± 0.3
Female 25%	25 %						
Initial	4.4 ± 0.3	3.0 ± 0.3	35.2 ± 5.3	0.0	0.7 ± 0.6	63 ± 5.0	0.6 ± 0.3
Final	4.6 ± 0.3	5.8 ± 0.5	39.3 ± 3.3	0.0	3.0 ± 0.9	57.4 ± 3.6	0.9 ± 0.4

*Means of 18–36 samples per treatment, ± standard errors

Source: Adewusi et al., in press

Table 19: Urine analysis of male and female human volunteers fed 0, 15 and 25% acacia-incorporated diets. Means of 10–32 samples per treatment, ± standard errors

% of acacia	Total protein g/dL	Acid phosphatase µmole/mL	Alk. phosphatase µmole/mL	Bilirubin mg/dL
Male 0%				
Initial	0.25 + 0.02	4.10 + 0.03	4.26 + 0.02	0.25 + 0.02
1st week	0.60 + 0.04	4.93 + 0.05	4.24 + 0.03	0.69 + 0.01
2nd week	1.27 + 0.23	4.93 + 0.11	5.78 + 0.10	0.39 + 0.01
3rd week	0.49 + 0.06	6.97 + 0.36	1.45 + 0.13	0.61 + 0.05
Male 15%				
Initial	0.24 + 0.01	5.64 + 0.03	4.95 + 0.15	0.43 + 0.01
1st week	0.71 + 0.02	6.78 + 0.05	4.92 + 0.21	0.43 + 0.01
2nd week	1.20 + 0.14	5.87 + 0.04	4.39 + 0.04	0.46 + 0.01
3rd week	0.69 + 0.02	4.13 + 0.07	2.37 + 0.11	0.29 + 0.01
Male 25%				
Initial	0.25 + 0.01	6.42 + 0.08	6.81 + 0.08	0.37 + 0.00
1st week	--	--	--	--
2nd week	1.30 + 0.04	5.14 + 0.06	4.79 + 0.05	0.51 + 0.01
3rd week	0.70 + 0.06	4.06 + 0.06	3.77 + 0.05	0.59 + 0.01
Female 0%				
Initial	0.21 + 0.01	4.20 + 0.04	3.70 + 0.03	0.50 + 0.01
1st week	1.03 + 0.13	5.10 + 0.05	5.98 + 0.07	0.48 + 0.01
2nd week	0.69 + 0.01	9.40 + 0.18	6.41 + 0.22	0.60 + 0.01
3rd week	0.58 + 0.01	6.71 + 0.16	3.38 + 0.02	0.34 + 0.01
Female 15%				
Initial	0.24 + 0.02	14.0 + 0.05	4.44 + 0.05	0.50 + 0.02
1st week	0.23 + 0.01	5.39 + 0.03	3.67 + 0.01	0.49 + 0.02
2nd week	0.69 + 0.01	9.61 + 0.09	5.3 + 0.01	0.67 + 0.01
3rd week	0.62 + 0.00	6.27 + 0.07	3.15 + 0.02	0.33 + 0.01
Female 25%				
Initial	0.30 + 0.00	? + 0.08	7.86 + 0.08	0.60 + 0.00
1st Week	0.26 + 0.02	4.28 + 0.05	4.37 + 0.05	0.50 + 0.01
2nd Week	0.80 + 0.01	17.0 + 0.27	8.26 + 0.20	0.89 + 0.02
3rd Week	0.77 + 0.01	4.03 + 0.24	3.06 + 0.02	0.37 + 0.01

Source: Adewusi et al., in press

Table 20: Daily intake[1] (g / day) of crude protein, lipid, fibre, carbohydrate and total food energy, calculated basal metabolic rate and daily food energy requirement (MJ / day)

	Level of acacia incorporation		
	0%	15%	25%
Male			
Crude protein	87.4 ± 2.2	100.0 ± 3.1	136.4 ± 3.6
Lipid	99.1 ± 7.0	81.0 ± 3.8	171.2 ± 2.8
Fibre	99.9 ± 1.4	129.7 ± 3.8	171.2 ± 2.8
Carbohydrate	714.9 ± 9.7	657.4 ± 9.3	751.1 ± 12.5
Total food energy[2]	16.9 ± 0.8	16.8 ± 0.7	19.1 ± 0.7
Basal metabolic rate[3]	6.6	6.7	6.8
Food energy requirement[4]	11.2	11.4	11.6
Excess to requirement (%)	51	47	65
Female			
Crude protein	77.6 ± 2.8	108.9 ± 3.8	131.9 ± 3.5
Lipid	78.6 ± 5.5	89.7 ± 5.1	90.8 ± 4.5
Fibre	82.2 ± 2.1	137.4 ± 3.2	169.7 ± 2.9
Carbohydrate	622.5 ± 15.7	715.5 ± 15.0	736.3 ± 13.9
Total food energy[2]	14.5 ± 1.1	16.8 ± 1.0	18.1 ± 0.9
Basal metabolic rate[3]	5.3	5.3	5.3
Food energy requirement[4]	8.8	8.9	8.9
Excess to requirement (%)	65	89	103

[1] Weight of food eaten per person per meal was recorded over one week and proximate composition of sample meals determined (Adewusi et al. 1998b). Each value for protein, lipid, fibre and carbohydrate is a mean and standard deviation calculated from the food eaten by nine male or female volunteers over a seven-day period (i.e. each value is a mean and standard deviation of 63 readings).

[2] Total food energy was calculated by multiplying the individual volunteer's protein, lipid and carbohydrate intake by the Atwater value (4, 9 and 4 KCal/g respectively).

[3] Basal metabolic rate was calculated from the Schofield equation using age and body weight (kg) of individual volunteers.

[4] Food energy requirement was calculated as a multiple of BMR using the factor 1.7 for light/moderate work for men and 1.5 for light work for women. Allowance was also made for lactation.

Source: Adewusi et al., in press

Table 21: Proximate composition of some acacia seeds (% dry weight basis)

Samples	Moisture	Ash content	Crude fibre	Protein	Fat	Carbohydrate (by diff.)
A. colei 1995	4.5 ± 0.4[b]	3.3 ± 0.2[c]	7.12 ± 0.6[a]	32.34 ± 1.2[ab]	15.1 ± 0.8[ab]	42.1
A. colei 2002	4.5 ± 0.1[b]	4.4 ±0.05[b]	6.03 ± 0.5[a]	34.15 ± 0.8[a]	16.9 ± 1.0[a]	38.5
A. colei 2006	4.4 ± 0.2[b]	5.5 ± 0.05[a]	6.12 ± 0.2[a]	32.81 ± 0.5[ab]	13.8 ± 0.9[b]	41.8
A. colei 2009	7.6 ± 0.6[a]	3.3 ± 0.1[c]	7.06 ± 0.4[a]	30.67 ± 1.1[b]	15.5 ± 1.4[ab]	43.5
A. torulosa 2002	5.0 ± 0.2[a]	3.4 ± 0.1[a]	4.01 ± 0.4[a]	29.49 ± 1.5[a]	12.3 ± 0.8[a]	50.8
A. torulosa 2006	5.2 ± 0.1[a]	3.3 ± 0.03[a]	4.30 ± 0.5[a]	29.62 ± 0.8[a]	13.8 ± 1.2[a]	49.0
A. elancantha	7.4 ± 0.5[a]	4.3 ± 0.2[a]	9.8 ± 0.2[b]	26.92 ± 0.4[b]	18.2 ± 0.2[a]	40.8
A. tumida	5.7 ± 0.1[b]	3.2 ± 0.15[b]	12.8 ± 0.8[a]	29.60 ± 0.9[a]	12.6 ± 0.4[b]	41.8

Table 22: Effect of storage on true protein and protein digestibility of some acacia seeds (g/100g DW)

Samples	% yield	Protein	True protein	Digestible protein	% Protein digestibility
A. colei 1995	57.9	32.3 ± 1.2^{ab}	18.30 ± 0.09^{c}	21.81 ± 0.0^{b}	67.4
A. colei 2002	44.12	34.2 ± 0.8^{a}	21.00 ± 0.7^{ab}	24.05 ± 0.6^{a}	70.4
A. colei 2006	55.54	32.8 ± 0.5^{ab}	20.50 ± 0.5^{b}	23.63 ± 0.4^{a}	72
A. colei 2009	43.78	30.7 ± 1.1^{b}	22.00 ± 0.2^{a}	22.44 ± 0.2^{b}	73.1
A. torulosa 2002	51.51	29.5 ± 1.5	17.20 ± 0.4	20.18 ± 0.2	68.2
A.torulosa 2006	55.54	29.6 ± 0.8	21.90 ± 1.1	21.86 ± 0.6	73.8
A. elancantha	45.48	26.9 ± 0.4^{b}	20.00 ± 0.8^{b}	15.11 ± 0.5^{a}	56.1
A. tumida	51.00	29.60 ± 0.9^{a}	23.18 ± 0.3^{a}	16.77 ± 0.1^{a}	56.6

Table 23: Effect of Storage (years) on Mineral Content of *A. colei* (mg / kg DW)

Mineral	*A.colei* 1995	*A. colei* 2002	*A. colei* 2006	*A. colei* 2009	*A. torulosa* 2002	*A. torulosa* 2006
Pb	17.8 ± 2.28^{a}	17.5 ± 2.8^{a}	15.8 ± 2.8^{a}	10.9 ± 2.9^{a}	13.8 ± 3.5	12.5 ± 6.3
Cr	4.08 ± 0.4^{b}	5.96 ± 1.9^{b}	7.2 ± 0.95^{ab}	10.6 ± 2.6^{a}	6.0 ± 0.0	27.5 ± 0.0
Zn	15.8 ±3.35^{a}	12.5± 0.32^{a}	16.9 ± 2.4^{a}	16.2 ± 2.6^{a}	23.7 ± 2.0	23.1 ± 9.7
Cu	ND	ND	ND	ND	3.9 ± 0.5	ND
Fe	224 ± 4.5^{bc}	204 ± 7.4^{c}	257 ± 8.8^{b}	383 ± 12^{a}	348 ± 44^{a}	256 ± 33^{b}
Mn	32.2 ± 0.2^{a}	26.2 ± 1.8^{b}	20.7 ± 0.8^{c}	20.7 ± 0.5^{c}	13.4 ± 0.5	13.3 ± 0.6
Ni	2.4 ± 0.8^{ab}	3.3 ± 0^{a}	2.7 ± 0^{ab}	1.7 ± 0.6^{b}	ND	ND
Ca	12.8 ± 4.6^{a}	15.7 ± 2.4^{a}	19.1 ± 3.5^{a}	18.5 ± 0.4^{a}	55.7 ± 9.0	54.0 ± 2.2
Mg	113.4 ± 4.3^{d}	138 ± 9.0^{c}	160 ± 10^{b}	190 ± 2.4^{a}	39.0 ± 0.5	37.0 ± 1.6

Table 24: Fatty acid profile of *A. colei* (as % of the total fatty acids)

Fatty acids	*A. colei* 1995	*A. colei* 2002	*A. colei* 2006	*A. colei* 2009
C12:0	0	0	0.206	0
C14:0	0.174	0.0527	0.188	0.165
C16:0	10.047	12.023	10.841	15.55
C18:0	15.166	21.062	22.226	20.964
C20:0	1.641	1.166	1.729	1.000
C21:0	0.295	0.231	0.064	0.122
C24:0	0.136	0.380	0.616	0.260
C16:1	0	0.046	0	0.192
C18:1	15.217	19.733	19.421	17.703
C20:1	0.087	0.136	0.115	0.135
C18:2	49.826	38.654	39.255	39.916
C18:3	0.634	0.629	0.704	0.225
C20:3	4.153	3.152	3.103	2.503
C20:5	0.776	0.641	0.907	0.469
C22:2	0.329	0.251	0.357	0.177
C22:6	1.615	1.840	0.265	0.614
SFA	27.459	34.915	35.87	38.06
MUFA	15.304	19.92	19.536	17.838
PUFA	57.333	45.167	44.591	43.904

Table 25: Amino acid profile of *A. colei* seeds harvested at different years

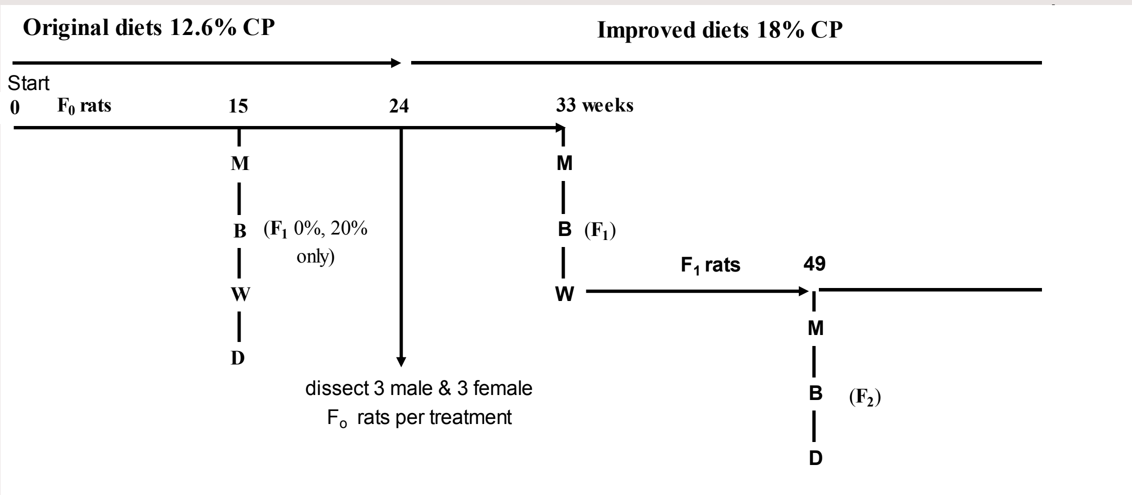
Amino acid	*A. colei* 1995	*A. colei* 2002	*A. colei* 2006	*A. colei* 2009
Essential amino acids				
Ileu	3.86	3.50	3.63	3.71
Leu	8.31	6.74	8.10	6.22
Lys	5.08	4.12	4.64	5.18
Met	2.18	1.92	2.29	2.31
Cys	1.32	0.88	1.20	1.40
Phe	4.44	4.11	4.52	4.52
Tyr	3.84	2.92	3.53	3.72
Thre	3.31	2.86	3.25	3.33
Val	4.76	3.91	4.64	4.65
His	2.09	2.06	2.09	2.14
Non-essential amino acids				
Arg	3.59	3.08	3.33	3.61
Asp	7.65	6.57	7.44	7.91
Ser	3.32	2.75	2.86	3.46
Glu	12.32	9.59	10.67	11.21
Pro	4.71	3.75	4.46	4.50
Gly	4.62	3.81	4.67	4.67
Ala	3.86	3.35	4.05	4.52

Table 26: Available lysine content of some acacia seeds

Sample	Total lysine g/100g protein*	Available lysine g/100g protein	% reduction
A. colei 1995	5.08	3.92 ± 0.11	22.8
A. colei 2002	4.12	3.80 ± 0.12	7.7
A. colei 2006	4.64	4.32 ± 0.03	6.8
A. colei 2009	5.18	4.93 ± 0.02	4.8
A. torulosa 2002	3.24	3.20 ± 0.05	1.2
A. torulosa 2006	3.15	3.11 ± 0.04	1.2
A. tumida	6.94	5.91 ± 0.1	14.8
A. elancantha	7.22	6.19 ± 0.05	14.2

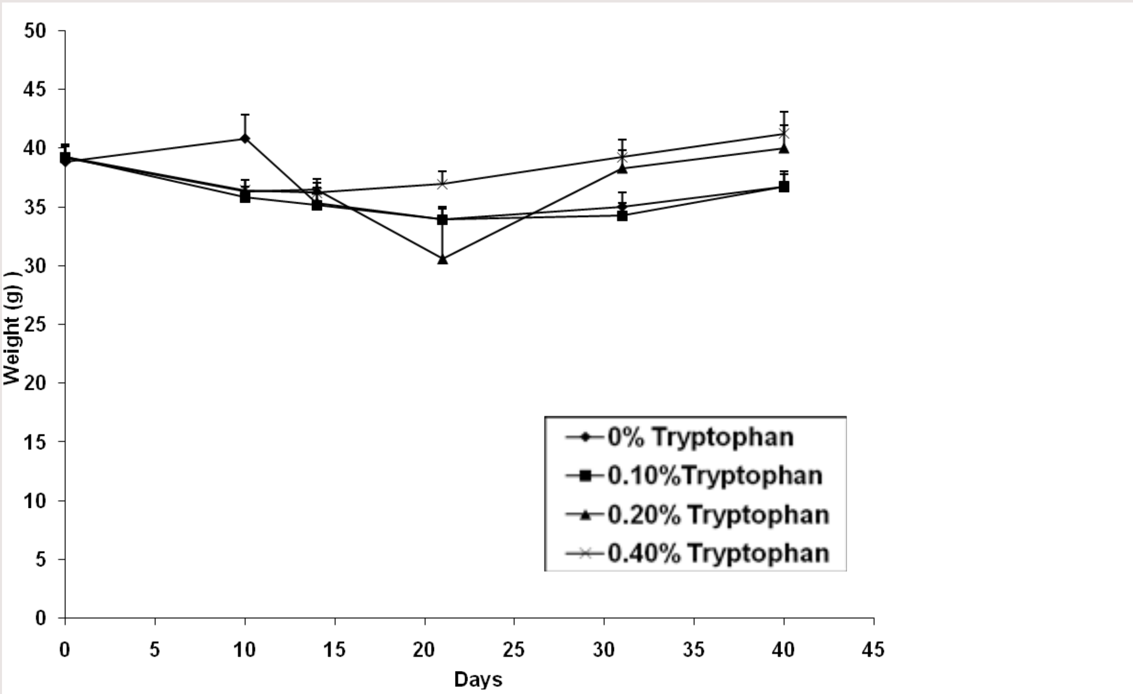
*Culled from Table 25

Figure 1: Flow chart of the reproductive study over three (3) generations



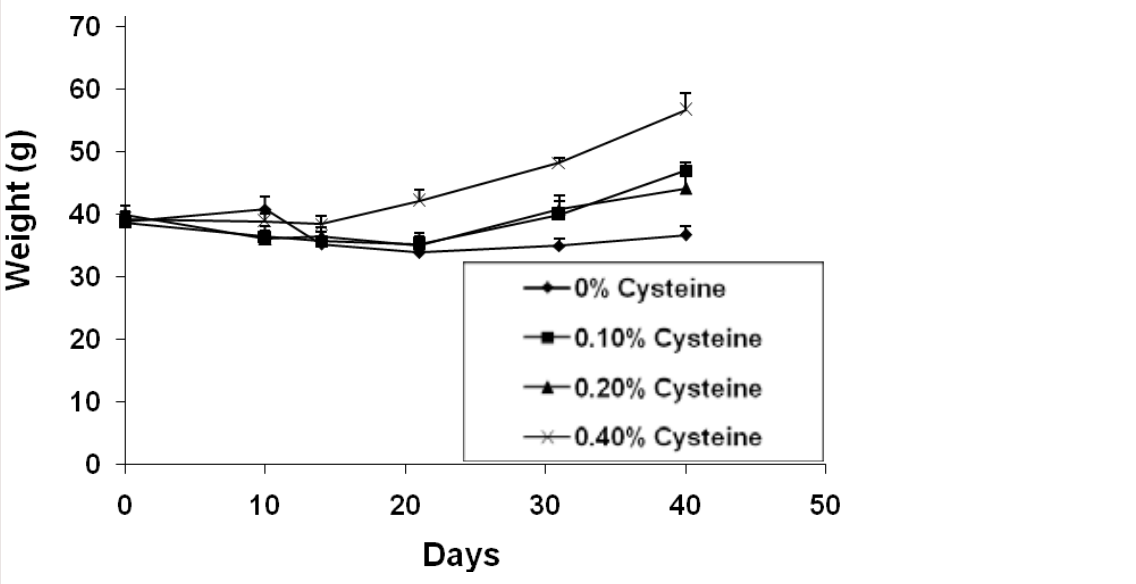
Source: Adewusi et al., (2006a)

Figure 2: Weight gain of rat fed with tryptophan-supplemented acacia diets



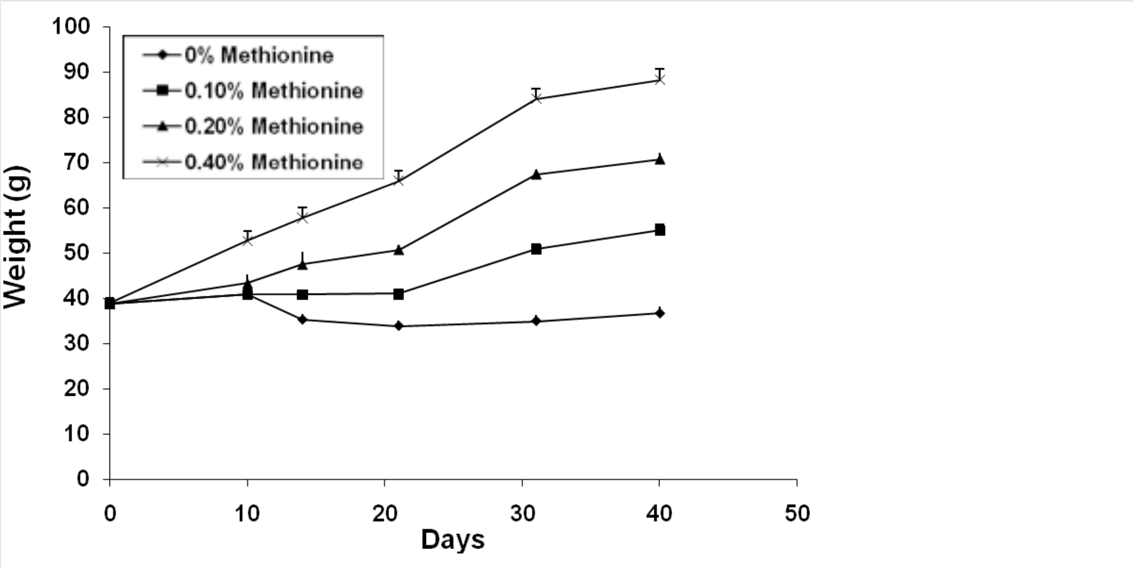
Source: Falade et al. (2011) in press

Figure 3: Weight gain of rats fed cysteine-supplemented acacia diets



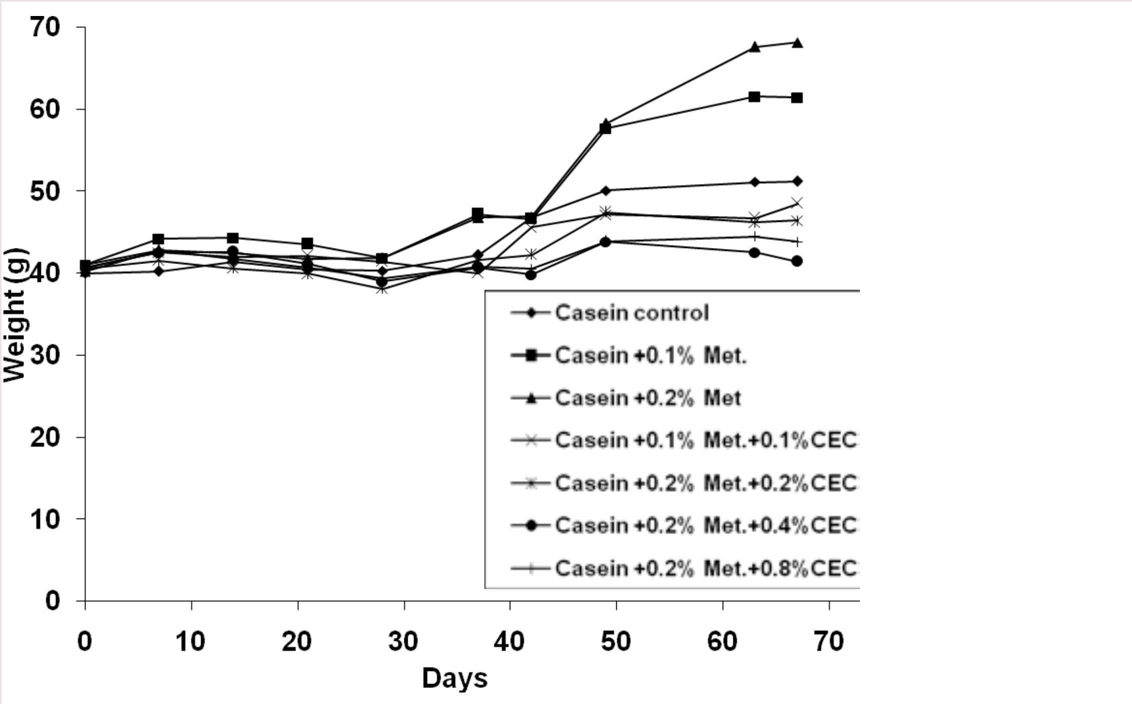
Source: Falade et al. (2011) in press

Figure 4: Weight gain of rats fed methionine-supplemented acacia diets



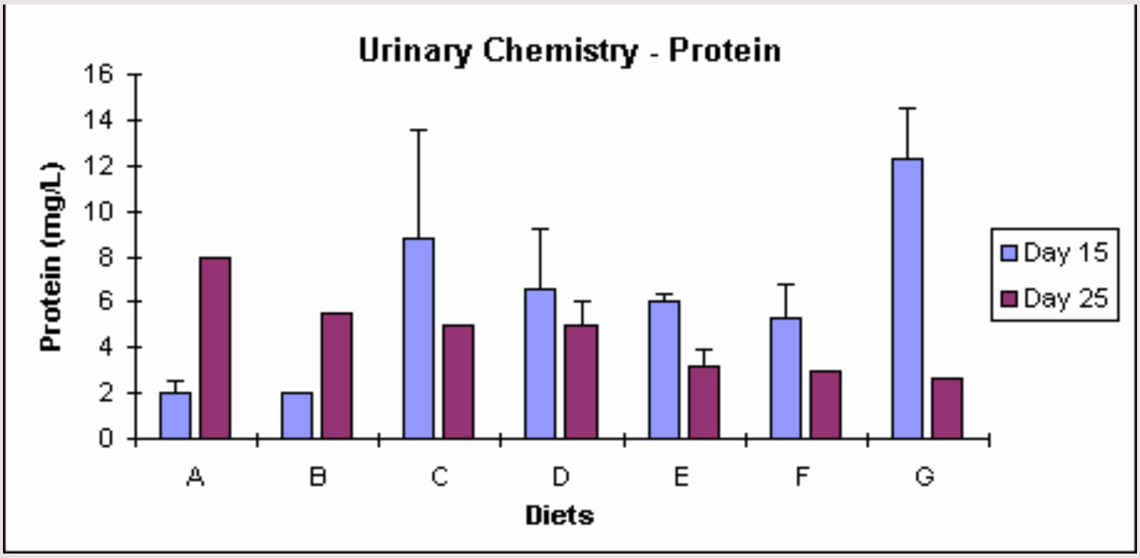
Source: Falade et al. (2011) in press

Figure 5: Weight gain of rats fed casein supplemented with CEC and methionine diets



Source: Falade et al. (2011) in press

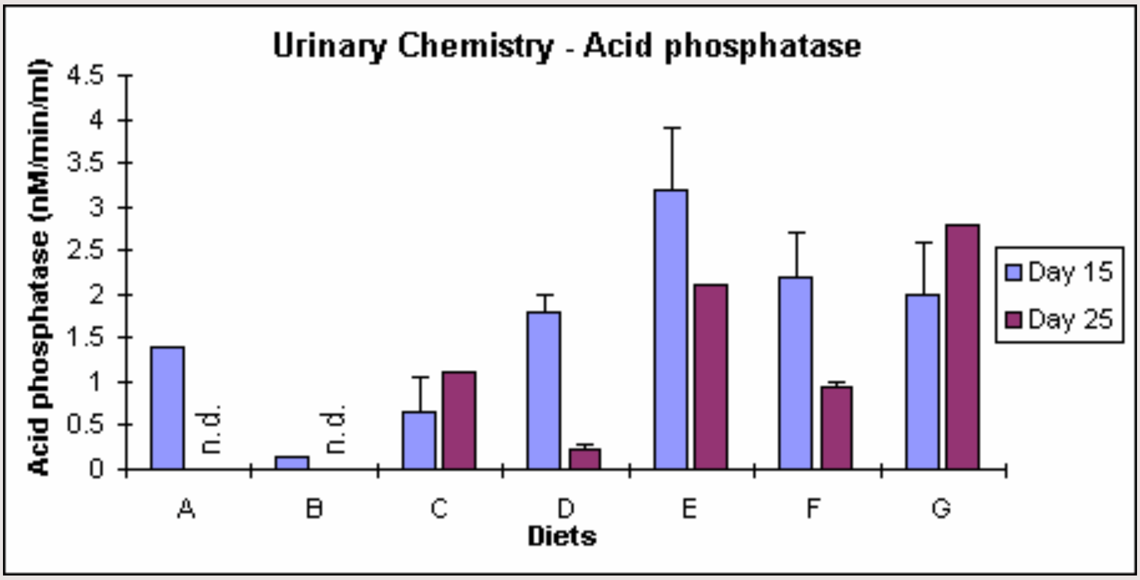
Figure 6: Urinary protein of rats fed *A. colei*-complemented different carbohydrate sources



Starch/casein/acacia, Starch/acacia, Cassava/acacia, Starch/casein/acacia, Starch/acacia, Cassava/acacia, White acha/acacia, Brown *fonio*/acacia, Millet/acacia, and Red Sorghum/acacia diets are coded A, B, C, D, E, F and G, respectively.

Source: Falade et al. (2008b)

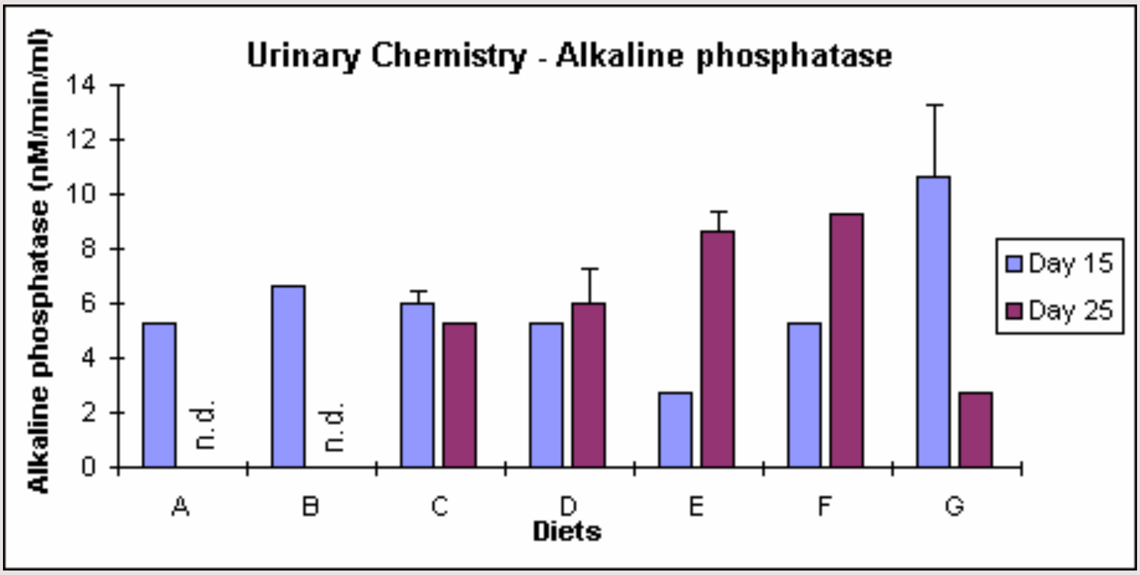
Figure 7: Urinary acid phosphatase activity of rats fed *A. colei* complemented with different carbohydrate sources



Starch/casein/acacia, Starch/acacia, Cassava/acacia, White acha/acacia, Brown *fonio*/acacia, Millet/acacia, and Red Sorghum/acacia diets coded A, B, C, D, E, F and G, respectively.

Source: Falade et al. (2008b)

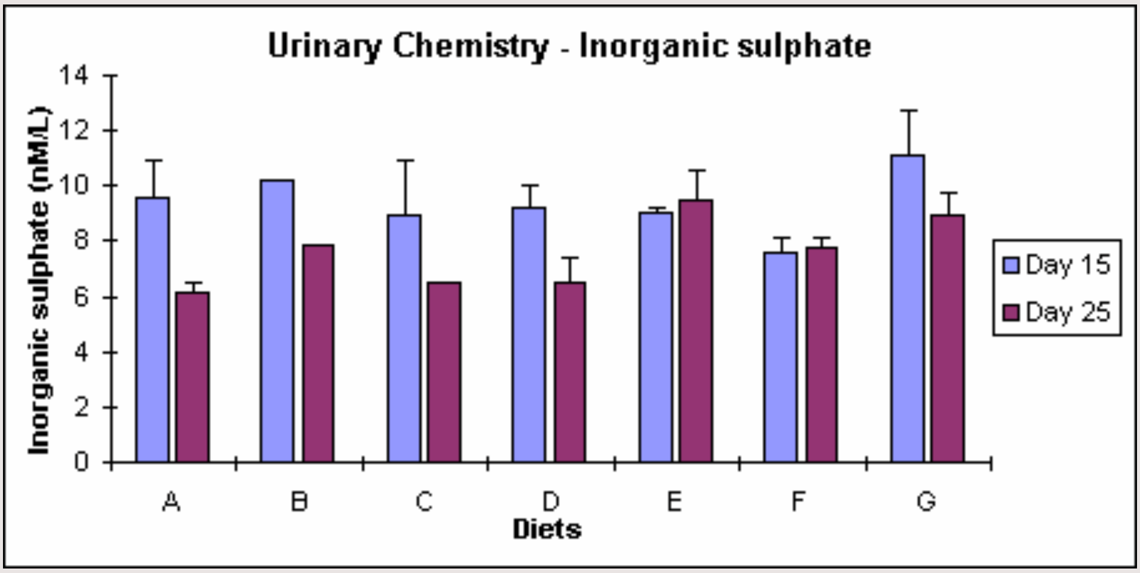
Figure 8: Urinary alkaline phosphatase of rats fed *A. colei* complemented different carbohydrate sources



Starch/casein/acacia, Starch/acacia, Cassava/acacia, Starch/casein/acacia, Starch/acacia, Cassava/acacia, White acha/acacia, Brown *fonio*/acacia, Millet/acacia, and Red Sorghum/acacia diets are coded A, B, C, D, E, F and G, respectively.

Source: Falade et al. (2008b)

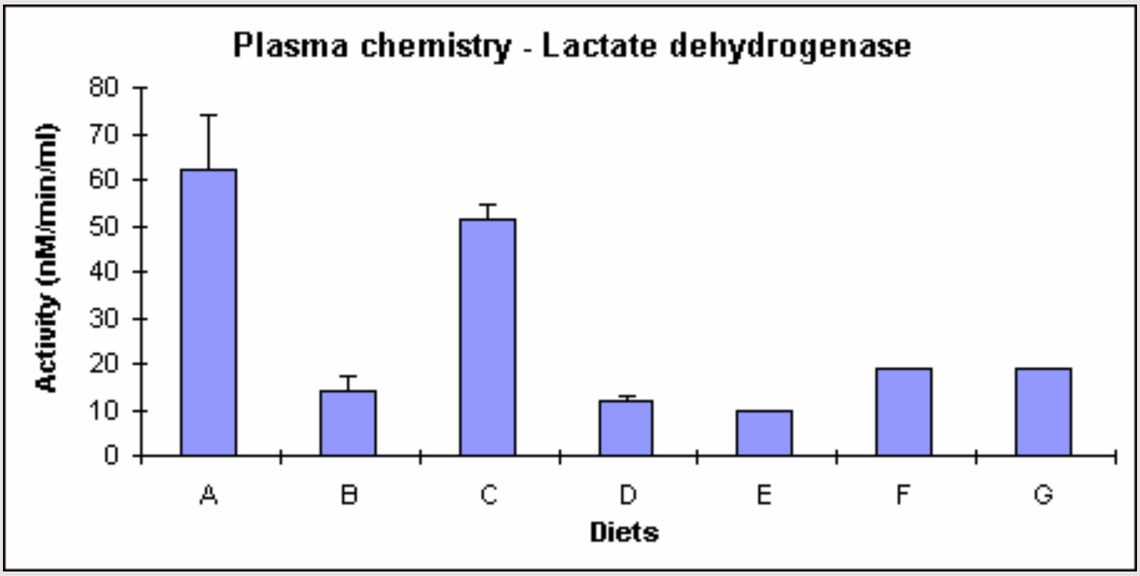
Figure 9: Urinary inorganic sulphate of rats fed *A. colei* complemented different carbohydrate sources



Starch/casein/acacia, Starch/acacia, Cassava/acacia, Starch/casein/acacia, Starch/acacia, Cassava/acacia, White acha/acacia, Brown *fonio*/acacia, Millet/acacia, and Red Sorghum/acacia diets are coded A, B, C, D, E, F and G, respectively.

Source: Falade et al. (2008b)

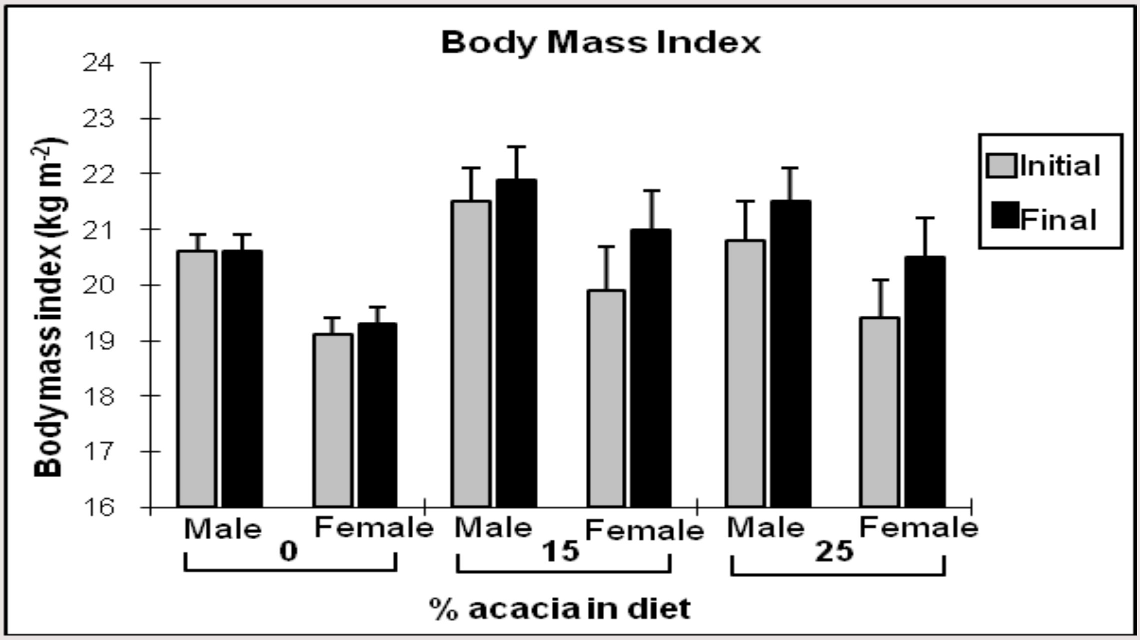
Figure 10: Plasma lactate dehydrogenase of rats fed *A. colei* complemented different carbohydrate sources



Starch/casein/acacia, Starch/acacia, Cassava/acacia, Starch/casein/acacia, Starch/acacia, Cassava/acacia, White acha/acacia, Brown *fonio*/acacia, Millet/acacia, and Red Sorghum/acacia diets are coded A, B, C, D, E, F and G, respectively.

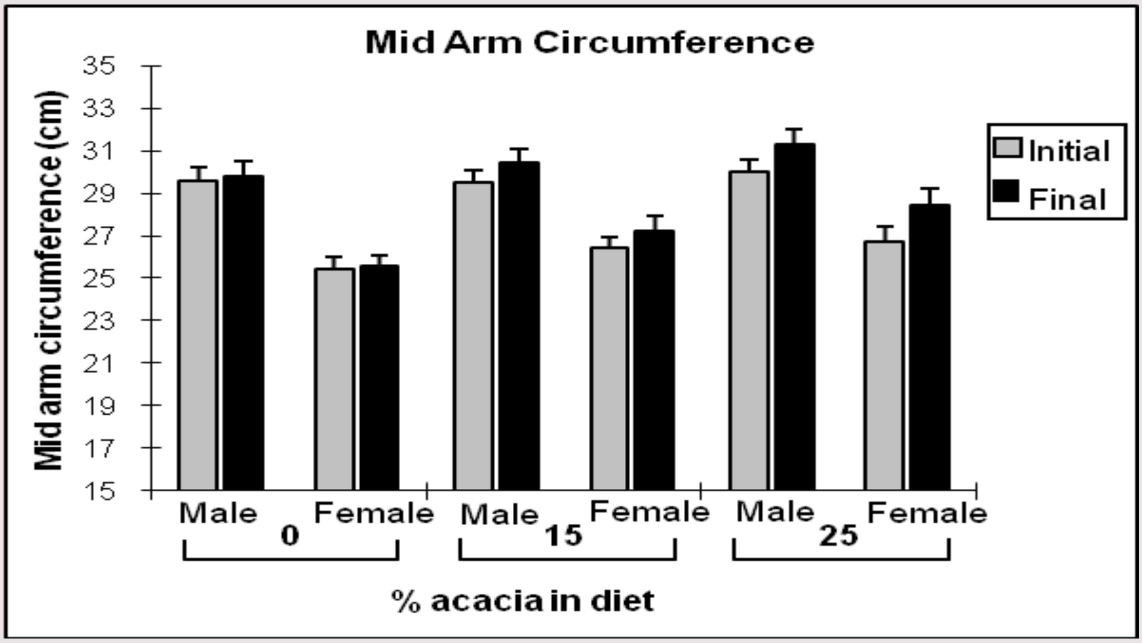
Source: Falade et al. (2008b)

Figure 11: Body mass index of human volunteers at the beginning and end of the feeding trial



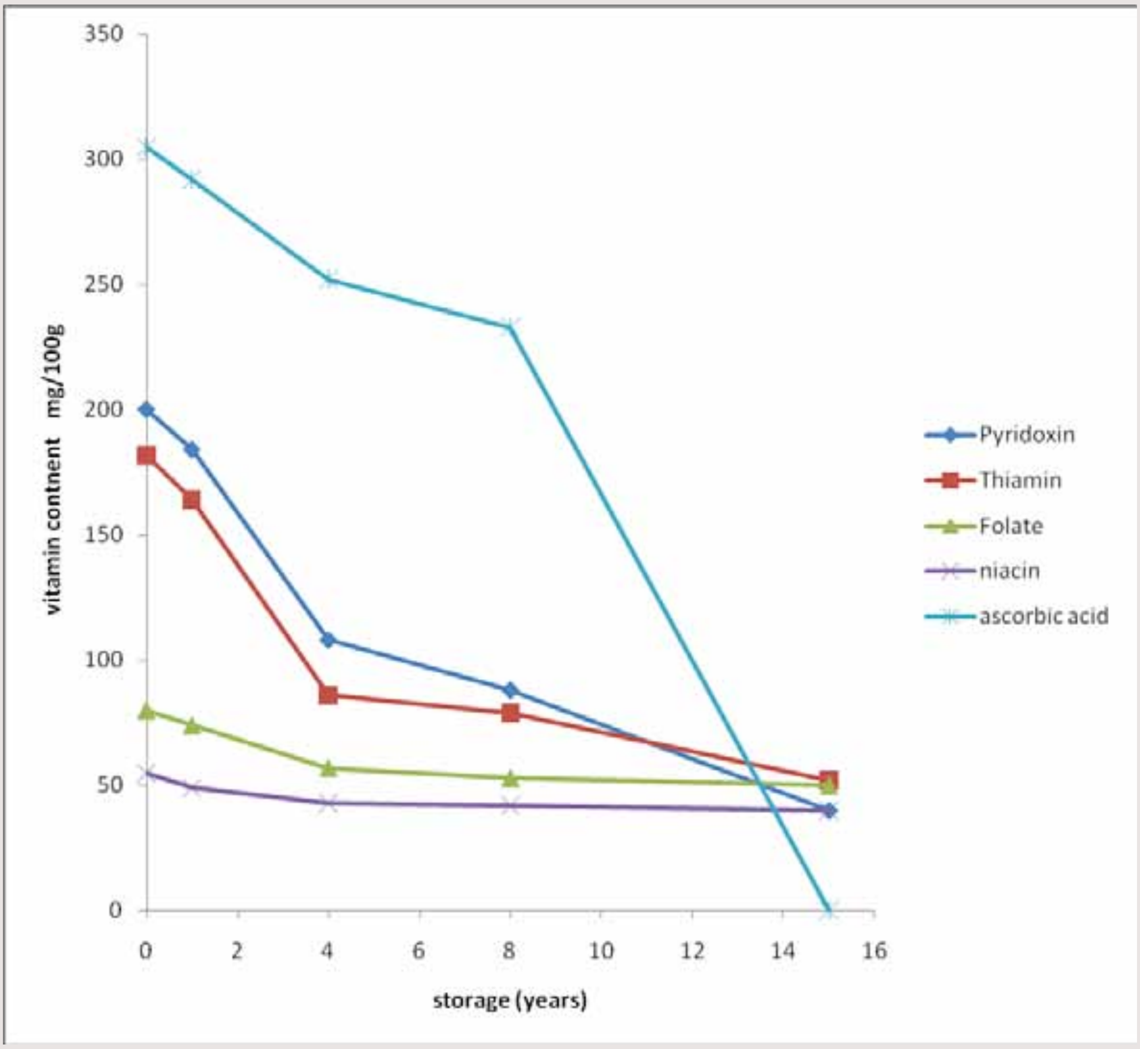
Source: Adewusi et al., in press

Figure 12: Mid-arm circumference of human volunteers at the beginning and end of the feeding trial.



Source: Adewusi et al., in press

Figure 13: Changes in the water soluble vitamin content of *A. colei* seed stored for different periods



Source: Adewusi et al., in press

A little bit more. A little bit better: Socialising acacia for food security

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Australian acacias are a suite of trees that include several species that could make a real difference to food security in the semi-arid tropics. The cultivation of Australian acacias in semi-arid Africa for food is a relatively new enterprise, and unsurprisingly, and despite much good work, there is much yet to be discovered with regard to acacia seed production and utilisation. It is clear however, that acacias can deliver a wide range of benefits: to natural and agricultural systems, to farm incomes and to family nutrition (Rinaudo and Cunningham, 2007; Adewusi, Falade et al, 2006; Harwod, 1994). All such benefits help to build livelihoods and resilience in rural communities, and as such are a valuable contribution to food security. In this paper I want to show that the promise of acacia can be realised even if seed production figures never make their way onto the national agricultural data record, even if bulk food production is not increased by a very large percentage, even if household income only rises by a small percentage.

The real promise of acacia is that it puts better nutrition for children into the hands of parents, potentially, in many cases, tipping the balance for the better. The reality of child malnutrition is that it only rarely looks like the media images of famine. Child malnutrition, in the vast majority of cases, is a chronic condition wherein the victim is in deficit for a given set of crucial nutrients, but is not "starving". Quite simply, in many marginal cases – and these are the vast majority – simply a little more food, and/or better quality food, can make a big difference (Keatinge and Easdown, 2006). If young children and infants are fed a little better, far fewer will slide into malnutrition, and the need for costly interventions will be greatly reduced.

Significant work has been completed, or is underway, on several species of acacia which demonstrates a wide range of attributes that could contribute to environmental amelioration, improved livelihood options and more secure food supplies for rural populations in the semi-arid tropics of Africa. Rinaudo et al (2002) have detailed the many benefits that are gained when Australian acacia trees are planted in the agricultural landscape, including reduced wind speeds, fuelwood production, improved soil nitrogen and the production of edible seed. Adewusi et al (2011) have completed a comprehensive study of the nutritional potential of the seed of *A. colei* and *A. tumida*. This study included a human volunteer trial that indicated

that acacia seed can be safely and beneficially incorporated into a Sahelian cereal-based diet at up to 25 percent (Adewusi et al, 2006). Cunningham et al (2009) have conducted extensive provenance trials across several species near Maradi, in Niger, and have documented the productivity of both seed and wood across a decade. Cunningham et al (2008) have developed an agroforestry system that effectively incorporates the benefits of a number of conservation farming techniques with the protective, and productive potential of acacias, to generate farm incomes as much as three-fold higher than in “normal” Nigerien farming systems. The author (Yates, 2010), demonstrated how acacia seed could be used to improve infant nutrition in Niger, and also how the millions spent in food aid every year could be harnessed to effect a landscape-wide transformation to agroforestry by employing acacia seed as the basis of a nutritional support product.

Focussing for best effect: child nutrition

Access to quality protein (and other nutrients) tends not to be equal in many very poor societies. Men tend to eat more meat and to eat it more often. Children under five, on the other hand, despite having the greatest needs per body weight, tend to receive the least, and the lowest quality foods (Hampshire et al, 2009; Cooper, 2009). In the Republic of Niger, child malnutrition levels have been described as a “permanent emergency” (Maranon, 2007; du Vachat, 2010). In Ethiopia, a national survey carried out in 2005 “… showed that 47% of children under five in Ethiopia were stunted. Similarly, 27% of women of childbearing age were found to suffer from chronic energy deficiency” (Ministry of Health, 2008). These figures indicate a serious and chronic problem in the nutrition of infants and children that stretches across even “normal” agricultural seasons. It is widely agreed amongst nutritionists and humanitarian relief experts that the greatest burden of suffering in countries such as Niger and Ethiopia falls to the young, and that this where major research and intervention efforts need to be focussed (c.f. Awino, 2011). I add the caveat that such efforts must focus on increasing the ability of poor rural families to produce or obtain adequate supplies of appropriate foods to meet their needs from their own environment, rather than following the subtly disempowering model where protein and micronutrients are imported and child nutrition is medicalised (c.f. Palmer, 2009).

Poverty alone does not explain why so many infants and young children are malnourished, since in the 2005 famine in Maradi, Niger, the children of even relatively well-off families were presenting to clinics with symptoms of malnutrition in surprising numbers (Cooper, 2009), thus cultural factors need to be considered in any explanation. In Niger, for example, the early cessation of breastfeeding is common – as early as four months of age – by a large proportion of mothers. Once weaned, infants are typically fed a porridge of millet called “kunu”. However, as one commentator put it: “A diet of millet kunu alone is equivalent to a diet of bread and water” (Shepherd, cited in MSF, 2007). Protein is low, and is of poor quality, whilst micronutrients such as iron, zinc, calcium and Vitamin A are all far below the levels required by a growing body. A rapid decline in growth rate and, for many, a slide in chronic malnutrition is starkly evident in Nigerien infants from 4 to 6 months of age (Hampshire 2009). The addition of some goat’s milk or meat into this diet would make all the difference, however meat is a very rare treat, and precious few poor households have a goat. Importantly, no amount of additional millet kunu beyond that needed to provide for energy needs will improve the nutrition of these children. What they need – more protein and more micro-nutrients – is not to be found in millet.

In Tigrai, Ethiopia children tend to be breastfed much longer than in Niger – 12 months is normal, 24 months not unusual. Nevertheless, there is a clear decline in growth rates from around 9 months old, since at this age, energy and protein needs start to exceed what is available from their mothers' milk (Gebriel, 2000). Tigrain children are fed a gruel called "sebqo", typically made from wheat, that being the cereal most widely distributed as food aid. (Most Tigrain farmers are able to produce only around a quarter of their annual food needs). Wheat-based sebqo is in every respect just as poor a food for a child as is millet kunu: it provides energy and some protein, but it is inadequate in terms of key amino acids and is also low in many micro-nutrients.

What can sometimes be missed in thinking about food security is that that the margin between a sufficiency of food and malnutrition can be quite small. This margin may, in many cases, be bridged by "small do-able actions" that farming families can take, and so supply to infants and children, a little bit more food, and a little bit better food (c.f. Alive and Thrive, 2010). Growing and utilising the thus-far little-known Australian acacias, and the well-known moringa tree may provide be able to provide to households enough of the nutrients that hitherto have been in short supply to bridge this gap.

Acacia nutrition

The diet of poor farmers in sub-Saharan Africa is usually heavily dependant on cereals such as maize, sorghum and pearl millet. A diet of cereal, with little by way of pulses, little dairy and almost no meat, is likely to be chronically low in protein, and especially the indispensible amino acid, lysine. Without sufficient of any of the indispensible amino acids, a lot of the protein a person does eat cannot be properly used. Acacia seed, along with well-known legumes such as soybean, chickpeas and lentils, is high in lysine. Thus it is a good complement to a cereal-based diet, with the reservation that the sulphur-containing amino acids methionine, tryptophan and cysteine may become the next limiting factor(s). Acacia seed is a good source of carbohydrate, with respectable levels of digestible protein and good levels of many micronutrients, especially minerals, though levels of some micronutrients, notably vitamin A, are low (Adewusi et al, 2011; Adewusi et al, 2006). For those poor rural families who are able to afford little or no animal products in their diets, the addition to the diet of leaf from *Moringa oleifera* or *Moringa stenopetala* could be crucial in meeting these shortfalls (Jiru et al, 2006).

In Niger, the addition of acacia seed to a millet kunu at around 15–20 percent can add significantly to protein availability and quality, and increases the levels of some micronutrients (Adewusi, 2011; Yates, 2010). It is important to note however, that many crucial micronutrients remain inadequate. Tigrain children, whilst supported through mother's milk in terms of most micronutrients (assuming the mother has a reasonable diet – which may not be a reasonable assumption), are still lacking in protein quality (amino acid balance) and in energy, particularly in the form of fat. The inclusion of acacia seed could make a significant contribution to energy availability, mainly as carbohydrate and a modest contribution to fat. Protein availability also will be significantly boosted, however there may still be a shortfall in the sulphur-containing amino acids. Acacia seed is therefore only a part of the solution, and moringa leaf is required to boost the availability of methionine, tryptophan and cysteine.

There may be alternatives to acacia seed as a pulse additive to traditional infant foods. In Tigrai, pulse crops such as chickpeas could serve the purpose. In Niger, cowpeas are a common crop that would seem to be suitable. There are two problems, however: firstly, cowpeas are viewed as a cash crop, and most are exported to relatively wealthy Nigeria. Secondly, cowpeas are not generally considered to be a food suitable for infants. The basis for this observation may lie in the fact that cowpeas contain very high levels of tripsin inhibitors (Adewusi et al, 2011), which can interfere with protein digestion. There are good reasons, in any case, why we should use acacia, and that is that cowpeas cannot grow on and rehabilitate degraded land, and chickpeas cannot be grown on dry, eroded limestone moutainsides; and neither of these annual crops can provide wood for the hearth.

Issues in adoption of acacia as a food

Building acceptance of a 'new' food like acacia seed needs to happen on two intimately entwined levels. Firstly, someone, be they farmers, government or entrepreneurs, needs to start growing (or importing) the product. That is, it has to become available. Secondly, people need to be convinced that the product is safe, and must see some benefit to consuming it. For acacia seed in Niger, the path has been long and hard, and after twenty years or so, a disappointingly few people see acacia seed as a valuable, let alone indispensible, part of their diet. Many farmers grow acacia, some for seed, some for wood, but few indeed grow acacia without the active encouragement and support of an NGO. There are problems and benefits in growing acacia on farms, and though the literature tends to be emphatic in emphasising the benefits, the occasional failure of the seed crop, and the tendency of acacia to compete for soil water with cereal crops cannot be discounted on the negative side. In any case, it is certainly true to say that for most farmers, the economic sense of growing acacia trees is not (yet) self-evident. Nevertheless, we should take heart that the potato was no overnight success in Europe (Hawkes and Francisco-Ortega, 1993), and I warrant that it took more than 25 years for maize to enthral Africa. The lack of a market for acacia seed may be a major factor limiting acceptance of the crop (Rowlands, 2009). It was observed, when the author began buying seed in the Maradi region in 2004, that tree planting increased, remedial management of many old trees was carried out (ie. pruning), and interestingly, household consumption of the seed rose. It is likely that the acceptability of acacia seed was given a great boost by the fact that someone was not just paying money for it, but expressing concern over quality and seed cleanliness; it was thus freed from the rather pejorative status of "famine food".

Acacia in household diets

The adoption of Australian acacia species as multi-use trees can be expected to make a significant impact on nutrition in poor rural communities. It is not just a matter of seed production, since by growing acacias in the agricultural system, the productivity of annual crops can be markedly improved through increased soil fertility and wind reduction, whilst the value of fuelwood produced can make a significant contribution to farm income, and income can be converted into food. Nevertheless, it is seed that I want to focus on, as a food source that can be produced even on severely degraded land, and which, as I have detailed above, can be a good source of protein and energy. If acacia use can be achieved in concert with moringa leaf and an oilseed[1] (such as moringa – but also peanut, sesame, linseed, etc.), then the result would be even better. A cereal-based diet that comprised 15–20 percent acacia seed, and 10 percent moringa leaf would have good levels of both protein and carbohydrate, and adequate levels of most micro-nutrients. If the acacia and moringa are produced on-farm or on degraded lands nearby, they will amount to a clear increase in the available food supply.

[1] The inclusion of sufficient fats in the diets of the poor poses the problem that edible oils are expensive and fetch high prices, so that farmers are inclined to sell this valuable nutritional component rather than eat it themselves. The same is true of high value/high protein foodstuffs such as eggs.

Acacia seed has been successfully added to a wide range of millet-based foods in Niger. Cunningham et al (2009), report that over twenty traditional Hausa recipes have been adapted to include acacia seed. Whilst it is true that widespread adoption of acacia has been disappointingly slow, the reason does not seem to relate to any dissatisfaction with food value, with farming families, virtually to a person, expressing approval both of taste and its value in sustaining workers in the field. It is ironic, given the intent of this paper, that anecdotal evidence in Niger suggests that acacia is so valued in the households who know of it, that the men are keeping it to themselves, and leaving precious little to the children. Given this experience in Niger, it seems certain that acacia will be a successful addition to East Africa staples such as "injera" and "ugali".

As the present time, only one species of Australia acacia – *A. colei* – has been comprehensively tested for nutrition and safety as food, including animal and human feeding trials (Adewusi, 2011). A similar testing regime is currently underway for *A. saligna* in Ethiopia, and is expected to be completed in the latter half of 2012. There are several other species with potential, some with the promise of seed production under low rainfall conditions, and these should be systematically screened for toxic and anti-nutritional factors, moving to a comprehensive program of testing for those species that show the most promise. Additional agronomic and silvicultural work will then be needed to identify the best provenances for any given region or primary purpose (e.g. wood, or seed).

Once acacia species have been demonstrated to be safe, a concerted education campaign will be required to teach people the benefits of acacia seed, and to inform them of how best to use it, both as a productive tree on the farm, and as a food. Where acacia trees are plentiful, people need to be encouraged to harvest, store and eat the seed. Where acacia trees are yet few in number, farmers need to be encouraged to plant trees, and governments and NGOs need to develop strategies by which large numbers of acacia trees can be planted on degraded lands with proper attention to ownership and plantation maintenance.

Getting acacia into the marketplace

Creating markets for acacia seed will help to improve temporal and geographic availability. The existence of a market would also provide additional incentives to grow and harvest acacia seed. There are two very good options for the development of markets for acacia seed. The first can be very rapid, the second will take two to five years to be realised fully.

Cereal banks

The complementarity of acacia seed with cereals means that many food aid interventions could be greatly strengthened through the inclusion of acacia. Cereal banks, for example have been established in many regions as a means of ensuring both availability and affordability of cereals during the annual "hungry gap", between the late dry season and the new harvest, as well as during other periods of food shortage, such as drought. Cereal banks have been crucial in reducing seasonal hunger, and in redressing the economic balance between wealthy grain entrepreneurs and the very poor. But how much more effective could they be if they kept in their stock the makings of a complete and balanced diet? Stocking acacia seed would go a long way to achieving this, and would enable people's millet supplies to last much longer. Supplies of dried moringa leaf powder would be an equally valuable addition to the cereal banks' stocks.

Food aid products

The need for nutritional support intervention by national governments and the international community in the semi-arid regions of Africa seems likely to increase in the coming decades, with the impact of population growth, land degradation and climate change. These interventions amount to many millions of dollars per year, and countless tonnes of food. Too often these "donations" have served the interests of the donor far better than that of the recipients, whilst importing and distributing large amounts of food can undermine the local agricultural economy, leading to a loss of incentive for food production.

Acacia seed offers the possibility that nutritional support products could be produced largely or wholly within the regions where they will be deployed in times of hardship. In broad terms, the protein can come from the acacia seed, the carbohydrate from a local cereal, the fats from peanut or other oilseed, and micronutrients from a tree such as moringa (Yates, 2010). The basic ingredients used will vary by region. What is important is that a complete food can be created from ingredients produced in the semi-arid environment, and that the cash that pays for the ingredients goes not to a wealthy farmer in the United States mid-west, but to a small farmer in Niger or Ethiopia. With this cash income a family can afford agricultural inputs, medicines, education for the children and/or savings; in other words, such an approach to emergency relief can yield powerful development outcomes that will build resilience and reduce the risk of disaster in the future. Such an approach, I might add, is consistent with current WFP policies that seek to purchase foods for distribution locally or regionally, and with their laudable initiative known as "P4P" – Purchase for Progress, though it will come as no surprise that acacia seed is not yet on the WFP agenda.

Conclusion

I want to propose that we could have a more complex understanding of food security. Food security, taken at a broad view, seems to be a matter of agricultural production levels, market efficiency, transport systems, governance and household livelihoods, and indeed appropriate attention to these factors will go a long way toward improving supplies of food and nutrition. But if we look at food security from the position of the most vulnerable individuals, that is infants, young children, the elderly and women, we see food security in a very different light. What we see from this perspective is an interplay of household livelihood with cultural values and behaviours and interpersonal power differentials. At a macro-level, we see a vulnerable society. At a micro-level we see malnourished children. At this micro level, quite small changes can make a difference. A bit more food. A bit better food. Adding acacia to the household diet does not simply result in better-fed children and adults; it will result in a healthier community. Adults will be able to work harder and be more productive, children will grow better, with stronger bodies and better mental capacity, and communities will be more resilient to the impacts of the inevitable shocks to livelihood that are the lot of rural people.

Drought is one thing. These disasters will always happen, and will be handled well or poorly as the case may be. But the type of grinding chronic malnutrition that creates "permanent emergencies" of countries like Niger, is optional. It is optional, and the solution can be put into the hands of the people who can most efficiently implement it: mothers and fathers.

References

Adewusi, S., Falade, M., & Harwood, C., (2011), Wattle as Food: Nutritional and Toxic Considerations, Conference presentation: "Wattle We Eat for Dinner? Australian Acacias for Food Security Workshop", 16-18th August, Alice Springs, Australia.

Adewusi, S., Falade, M., Oyedapo, B., Rinaudo, T. & Harwood, C. 2006. Traditional and Acacia colei seed incorporated diets in Maradi, Niger Republic. *Nutrition and Health*, 18, 161-177.

Alive and Thrive, (2010), *Practices, IYCF practices, beliefs, and influences in Tigray Region, Ethiopia.* Addis Ababa, Ethiopia; Alive & Thrive; Ethiopia.

Apodaca, C. 2008. Preventing child malnutrition: Health and agriculture as determinants of child malnutrition. *Journal of Children and Poverty*, 14, 21-40.

Cooper, B. (2009). Chronic nutritional crisis and the trope of the bad mother. In: Jean-Herve Jezequel and Crombe, X. (ed.) *A Not-So Natural Disaster: Niger 2005*. Columbia University Press.

Cunningham, P., Nicholson, C., Yaou, S., Rinaudo, A. & Harwood, C. (2008). Utilisation of Australian Acacias for improving food security and environmental sustainability in the Sahel, West Africa. In: *Underutilized Plant Species for Food, Nutrition, Income and Sustainable Development*, 2008 Arusha, Tanzania.

Gerbriel, A. 2000. Determinants of Weaning Practices. *Ethiopian Journal of Health Development*, 14, 183-189.

Hampshire, K., Casiday, R., Kilpatrick, K. & Pater-Brick, C. 2009. The social context of childcare practices and child malnutrition in Niger's recent food crisis. *Disasters*, 33, 132-151.

Harwood, C. 1994. Human food potential of the seeds of some Australian dry-zone Acacia species. *Journal of Arid Environments*, 27, 27-35.

Harwood, C., Rinaudo, A. & Adewusi, S. 1999. Developing Australian acacia seeds as a human food for the Sahel. *Unasylva*, 198, 57-64.

Hawkes, J., Francisco-Ortega, J., (1993), The early history of the potato in Europe, *Euphytica,* Volume 70, Numbers 1-2, 1-7.

Jiru, D., Sonder, K., Alemaye, L., Alemayehu, L., Mekonen, Y. & Anjulo, A. 2006. Workshop presentation: Leaf yield and Nutritive value of Moringa stenopetala and Moringa oleifera Accessions: Its potential role in food security in constrained dry farming agroforestry system. Moringa and other highly nutritious plant resources: Strategies, standards and markets for a better impact on nutrition in Africa. Accra, Ghana.

Keatinge, D. & Easdown, W. 2009. Hidden hunger: food security means balanced diets. *Issues*, 89.

Maranon, M., (2007) Niger: A crisis of acute, protracted poverty and vulnerability, Crisis Report, *The Humanitarian Response Index*, DARA

Ministry of Health, (2008) *Ethiopia National Nutrition Strategy*, Government of Ethiopia, Addis Ababa.

MSF, (2007), Starved for attention: Wake up to the crisis of malnutrition. In: MSF (ed.) *Campaign for Access to Essential Medicines*.

Owino, V., (2011) Challenges in New Product Development: A Case Study of Lipid-Based Nutritional Supplements/ Ready to Use Foods for Management of Acute Malnutrition in Resource Poor Settings and Potential Utilisation of Acacia Powder, Conference presentation: "Wattle We Eat for Dinner? Australian Acacias for Food Security Workshop", 16-18th August, Alice Springs, Australia.

Palmer, G. 2009. What is complementary feeding: A philosophical reflection to help a policy process. In: IBFAN-GIFA (ed.) *Discussion Paper.*

Rinaudo, A. & Cunningham, P. 2007. Australian Acacias as multi purpose agroforestry species for semi arid regions of Africa. *Muelleria*, 26, 79-85.

Rinaudo, A., Patel, P. & Thomson, L. 2002. Potential of Australian Acacias in combating hunger in semi-arid lands. *Conservation Science*, 4, 161-169.

Rowlands, C. 2010. *Niger Acacia Market Analysis*. Burwood: World Vision Australia.

Du Vachet, E., (2010), *Hunger in the Sahel: A permanent emergency? Ensuring the next drought will not cause another humanitarian disaster,* Oxfam, London.

Yates, P., (2010), *Australian Acacias: The Potential to Combat Child Malnutrition, Build Agricultural Resilience and Support Adaptation to Climate Change in Semi-Arid Africa,* Report to World Vision Australia.

Enhancing livelihoods through environmental restoration, improving food security and farm resilience in the semi-arid tropics: The Farmer Managed Agroforestry Farming System

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Introduction

Niger is one of the poorest and least-developed countries in the world. Ninety per cent of the population (about 15 million) are subsistence farmers or herders who depend entirely on agriculture for their survival. These communities are becoming particularly vulnerable and face enormous challenges for their survival. Climate change, diminishing and unreliable rainfall, traditional monoculture cropping practices, high population growth, frequent famines, high de-forestation rates and biodiversity loss have led to severe environmental degradation and impoverished soils. This has resulted in poor crop yields, high malnutrition rates and extreme poverty; a growing humanitarian crisis is predicted for the future.

In response to these enormous challenges, the faith-based organisation Serving in Mission (SIM) has worked with farmers for over 30 years and developed a suite of integrated development activities to enhance livelihoods in the Maradi area (see Maradi Integrated Development Program (MIDP) Technical Manual 2001).

More recently these successful and sustainable agricultural components have been combined into an integrated farming system called "The Farmer Managed Agroforestry Farming System" (FMAFS) (Rinaudo and Cunningham 2008, Cunningham 2010). The system aims to overcome the main constraints to farming in the semi-arid tropics which include: soil and water erosion, low soil fertility, mono-culture cropping, lack of biodiversity, poor income generation and distribution and drought (Pasternak 2005). It seeks to make communities and crops more resilient to drought and climate change by incorporating agroforestry and environmental restoration to maximise biodiversity, improve food security, reduce malnutrition and regenerate indigenous trees.

Description of the FMAFS

There are five main components in the FMAFS

Figure 1: The components of the Farmer Managed Agroforestry Farming System

The Farmer Managed Agro forestry Farming System

Farmer Managed Natural Regeneration+
Multi-purpose Acacias+
Other Agro forestry trees+
Annual/Perennial crops+
Crop Residue Mulching

1. **Farmer Managed Natural Regeneration (FMNR)** is a simple reforestation technique developed by SIM in the early 1980s (Rinaudo 2007). The regenerating stems of trees from underground stumps are pruned and a limited number allowed to grow into multi-stemmed trees. The only input is the labour of the farmer who also decides on the number of trees/stems per field. In just over 20 years of using this technique 50 per cent of Niger's once-treeless farmland has experienced reforestation rates unprecedented elsewhere in Africa. This represents one of the great success stories in the field of climate change and agriculture and is perhaps "the single largest environmental transformation in Africa" (M. Hertsgaard, personal communication). FMNR directly leads to increased food security, income generation, biodiversity, environmental restoration, enhanced soil fertility and combats soil erosion. In the Maradi area alone, a conservative estimate values total additional income attributable to FMNR at USD17–23 million per annum and has contributed an additional million trees to the environment each year (Haglund et al 2011). There are now more than 6 million hectares of FMNR in Niger and the technique is spreading rapidly to other African countries through the African Regreening Initiative (C. Reij, personal communication).
2. **Crop Residue Mulching (CRM)** involves cutting the annual crop residues after harvest and laying this material on the soil surface. Ground cover is increased, soil organic matter and soil fertility are improved as termites cycle the nutrients into plant-available forms.
3. **Multi-purpose edible Australian acacias** (*Acacia colei, A. torulosa, A.tumida, A. elacantha*) thrive under Africa's semi-arid conditions. Domestication and evaluation programs over

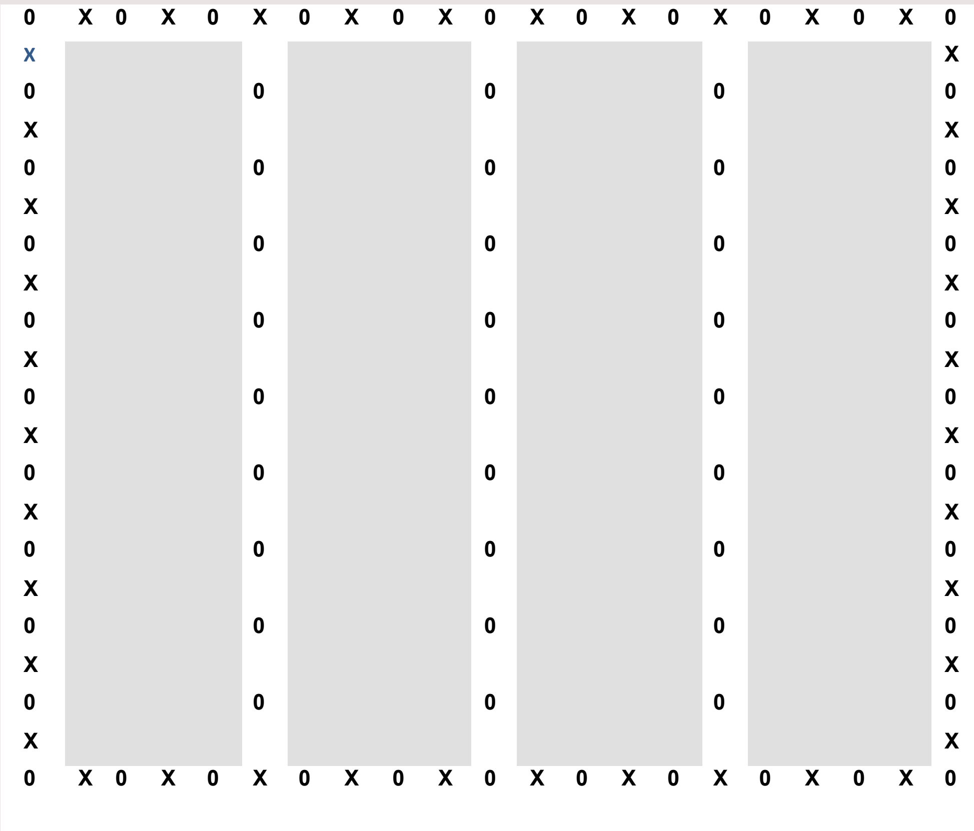
the last 20 years have led to a good range of types with wide adaptability (350–550 mm rainfall), high growth rates, seed and wood yield, nutritional value, and long-term seed storage capacity.

4. **Other valuable agroforestry trees** such as the pomme du Sahel (*Ziziphus mauritania*), tamarind (*Tamarindus indica*), boabab (*Adansonia digitata*) and moringa (*Moringa oleifera*, *M. stenapetala*) can be planted to complement FMNR and the acacias.
5. **Annual/perennial cash crops** such as millet, sorghum, cowpeas, peanuts, hibiscus, sesame, cassava, etc. are then planted with annual rotations between the tree rows.

Farm layout

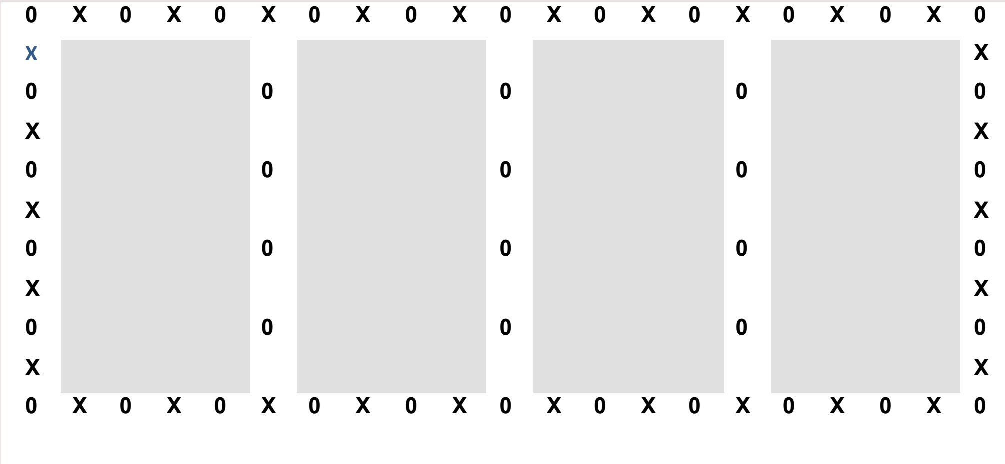
A typical FMAFS farm layout incorporates FMNR and CRM as the basic starting points. Australian acacia trees (at least two species) are then planted on the farm borders and in rows within the farm. The one-hectare model (Figure 2) has 107 acacia trees per ha and the half-hectare model has approximately 69–72 trees/ha (Figure 3). The acacia trees are pruned in the third year and every second year thereafter (just before the rainy season) to reduce moisture competition with annual crops. The acacias produce edible seed every year from the second year after planting. Annual crops are planted in rotation between the rows of trees. Farmers determine the density and layout of tree plantings and annual crops and the types and numbers of indigenous trees.

Figure 2. The Farmer Managed Agroforestry Farming System, one-hectare model



(100 x 100 m)
0 = *Acacia colei* (68) X = *Acacia torulosa* (40) Total acacia trees = 107 per ha.
Trees on the boundary are 5 m apart. Trees inside the borders are 10 m apart in rows with 25 m between rows. The rows of trees are planted across the prevailing wind direction.
Shaded area: FMNR with 40 to 120 trees per ha and annual/perennial crops in rotation.

Figure 3. The Farmer Managed Agroforestry Farming System, half-hectare model



(100 m x 50 m)
0 = *Acacia colei* (42) X = *Acacia torulosa* (30). Total acacia trees = 72 per ha.
Trees on the boundary are 5 m apart. Trees inside the borders are planted 10 m apart in rows with 25 m between rows. The rows of trees are planted across the prevailing wind direction.
Shaded area: FMNR with 20 to 60 trees per half ha and annual/perennial crops in rotation.

Promotion and adoption

The first FMAFS were established in 2005 as one-hectare model farms at two research and demonstration sites near Maradi (Maza Tsaye and Danja). Currently there are over 700 FMAFS in at least 27 villages, which directly benefit over 6000 people. Farmers' groups were formed in each village where the SIM project workers had built strong relationships over many years. Selected farmers (15–25 per village) were given training and assistance with farm layout. These farmers first undertook FMNR and CRM on their farms. Their village tree nurseries provided acacia and other useful trees for their farming systems. Annual crops were planted between tree rows and all labour was provided by the farmers themselves.

Important factors influencing adoption included:

1. A simple, low-cost and flexible farm layout.
2. SIM has ongoing bi-weekly follow-up in villages.
3. Field visits.
4. Annual tree nursery and farming systems training courses at a resource centre and research farm with FMAFS models.
5. Open days with demonstrations.
6. Weekly radio broadcasts.
7 Acacia food demonstrations in villages
8. The opening of a small market for the acacia seed to help develop interest in growing Australian acacia trees.

Demonstration FMAFS were also established in 11 villages with adjacent control-farms to compare the economic benefits of the system.

FMAFS training courses were completed in 2009 and 2010 with a range of non-government organisations (NGOs) such as World Vision, Adventist Development and Relief Association, Samaritans Purse, Christian Reformed World Relief Committee and Impact Niger working with Government agents. These courses, together with national acacia round-table meetings, have led to more widespread regional plantings of acacias with pilot FMAFS being established

in the regions of Zinder, Tahoua, Tillaberi and North Western Niger (A. Thacher, personal communication.)

Benefits

The FMAFS builds incrementally on FMNR as a more complex farming system so retains and promotes all the benefits of FMNR. Biodiversity is enhanced, the diversity of trees produce firewood, timber, fodder for animals, human food, medicines, land restoration and protection whilst also improving soil fertility. The Australian acacias are extremely fast growing, fix nitrogen and provide firewood, timber, mulch and food for humans (21% protein, 50% carbohydrate, 7% fat, with vitamins) and animals, while contributing to environmental restoration and crop protection. The range of annual crops gives food and income, and crop residues for animals and for CRM, which protects and restores soil fertility. Farmers have the flexibility to spread compost, animal manure, other organic residues or micro-dose mineral fertilisers to their annual cropping areas. Farm labour and income are spread throughout the year which gives resilience to families and helps to buffer against crop loss due to drought or insect attack.

Results, progress and impact

The FMAFS research trials (2007–2009) resulted in a two-fold increase in total farm income compared to the national average farm income (Table 1).

Table 1: Average annual economic benefits from a 1-ha FMAFS at Maza Tsaye (2007–2009)

FMAFS component	Product yield (kg/ha)	Value (cfa)	Value (USD)
Millet	640	24,000	48.84
Sorghum	475	21,400	43.55
Cowpeas	390	36,560	74.40
Hibiscus	270	13,500	24.47
Peanuts	25	2,300	4.68
Wood (Acacia)	120	3,000	6.11
Agropodon grass		6,000	12.22
Total		**106, 760**	**214.07**

Cfa = Central African franc

Control comparison. Traditional monoculture millet farm. Niger: Average annual millet and sorghum production 445 and 335 kg/ha (2003–2007).

The village demonstration FMAFS (managed entirely by farmers) have been extremely variable, but the results show average farm incomes (2007–2009) are from 68% to 500% higher than the adjacent control farms (traditional millet crops). These FMAFS have also recorded increases in the number of indigenous tree species and at least a three-fold increase in stem numbers (potential trees for income) after just three years.

The results of a successful half-hectare FMAFS farm are give in Table 2. Note the diversity of income sources, two-fold increase in crop income and five- fold increase in total farm income compared to the control (traditional millet crop). There was also an increase from three to indigenous tree species and a six-fold increase in tree stem numbers due to the FMNR from 2007–2009 (Table 3).

Table 2: Average annual economic benefits from a half-hectare FMAFS vs control farm at Magajin Kware (2007–2009)

FMAFS component	FMAFS (cfa)	Control (cfa)	% increase
Annual crops	34,630	11,460	302
FMNR wood	6,500		
Acacia wood	5,660		
Acacia seed	10,750		
Total	**57,540**	**11,460**	**502**

Table 3: Change in tree species and stem numbers in a half-hectare FMAFS at Magajin Kware (2007–2009).

Tree species	Stem numbers (2006)	Stem numbers (2009)
Guiera senegalensis	24	152
Bauhinia reticulata	-	18
Azadiradita indica	2	8
Faidherbia albida	2	2
Calotropis procera	-	2
Moringa oleifera	-	2
Boscia senegalensis	-	2
Total	**28**	**186**

Importantly, the FMAFS results in greater resilience to total crop failure which occurs on average at least every third year under traditional farming practice. The range of income sources from food crops (grain, acacia seed, fruit), firewood, animal fodder, etc. help to buffer against adverse events such as drought, insect attack or storms. Firewood is becoming increasingly expensive in the Maradi area and even more so in other areas of Niger. It is estimated that two to three hectares of well-managed FMAFS farms will provide adequate firewood for an average family for a year, yet also provide a surplus from food crops for sale and income generation.

In general, crop yields and food security are enhanced under FMAFS compared to traditional farming systems. Communities benefit from eating the acacia seed in two ways:

1. Food quality is enhanced by the high protein content of acacia seed.

2. Other grain stocks (e.g. millet and sorghum) last longer due to the “filling effect” when high-protein acacia flour is mixed with the traditional grains.

The FMAFS has lasting impact and contributes to environmental restoration through the natural regeneration of indigenous trees, increased crop/tree residues which improves soil fertility and structure and reduced soil erosion from wind and intense rainfall.

More recently, in 2009–2010, village farm FMAFS tend to favour acacias on farm boundaries and the farmers’ tree planting includes an equal mix of edible acacias and other useful exotic trees. More effort has been seen in compost production and CRM.

Component research: Acacia species selection, domestication and silvicultural needs

The MIDP and Sowing Seeds of Change in the Sahel (SSCS) project managed by SIM at Maradi have been the lead agency for edible acacia development. In collaboration the Commonwealth Scientific and Industrial Research Organisation, Australian Tree Seed Centre, National Agricultural Research Institute of Niger and the International Centre for Research in the Semi Arid Tropics there has been significant research and development of the edible acacias over the last three decades (Harwood et al 1999, Rinaudo et al 2002, Cunningham and Abasse 2008, Cunningham et al 2011). The MIDP searched widely for suitable indigenous plants with food potential in the 1980s and 1990s. Although a number of indigenous annuals and perennial fruit trees have been grown successfully (i.e. *Ziziphus* spp, *Poupartia birrea*, *Adansonia digitata*), none were comparable with the Australian acacias for growth rate, seed yield, nutritional value, long-term seed storage capacity and human food potential (Rinaudo et al 2002).

Acacia colei was found to be the most versatile edible acacia species for the Maradi area and was promoted as both a famine food (via food for work programs and as a protein supplement in a large range of local foods (Harwood et al 1999).

The promotion of *A. colei* as a new human food has still not led to widespread adoption of the species, but certain individuals and a significant number of villages in the Maradi area are using acacia food regularly in their diets and report significant improvements in nutrition and wellbeing (Cunningham et al 2011).

Further research and development of edible acacias by the SSCS team aims to overcome some of the weaknesses that have contributed to the slow uptake of *A. colei* (7–8 year life span, competition with crops, seedless years, lack of market, etc.). In addition, the focus has now broadened to multi-purpose trees (food, fuel wood, timber, mulch, erosion control, environmental restoration, etc.).

Provenance trials with other species such as *A. torulosa*, *A. tumida* and *A. elachantha* have led to the domestication of two types of *A. colei* variety *ileocarpa*, two branching and one tall type of *A. torulosa*, two types of *A. tumida* variety *kulparn* and one tall *tumida* variety. Five provenances of *A. elachantha* have been under evaluation since 2008 (Table 4). Both multi-purpose agroforestry and timber (pole) types are being selected for use in FMAFS, plantations and in degraded areas. Both *A. colei* and *A. torulosa* are being widely promoted.

Table 4: Domestication of edible Australian acacias by SIM at Maradi, Niger 2001–2011

Species	Variety	Years	Rainfall adaptation (mm)
A. colei	*Ileocarpa* (2)	1990–2008	350–550
A. torulosa	Tall	2002–8	400–600
	Branching (Elliot)	2002–8	400–600
	Wycliffe Well	2008–11	300–450
A. tumida	Kulparn	2004–8	400–550
	Kulparn (Sadore)	2009	500–650
	Tumida (tall)	2006–8	400–550
A. elachantha	Branching (5)	2008...	400–550+

Alongside the domestication process, the silvicultural requirements including seedling establishment, planting, tree establishment, pruning, coppicing, spacing, seed harvest and processing are being evaluated and refined.

Challenges and future research

Perceptions and tree ownership

The subsistence farmers in the Maradi area have been very resistant to change. Moving to agroforestry farming with trees has taken more than a decade as farmers traditionally view trees as weeds and competitors with their annual crops (Rinaudo, 2007). Prior to 2004 all trees in Niger were owned by the state. Although a tree ownership policy has still not been officially recognised in Niger, it is now generally understood that the farmers themselves own the trees on their land. This has greatly increased the farmers' confidence to allow trees to regenerate on their land. The planting of new trees and the subsequent tree care and protection by farmers is generally poorly practised, leading to poor tree survival.

Field establishment

Tree nurseries are still the most reliable way of growing the acacias and other trees. This is costly and time consuming. Direct seeding of the Acacias has been unreliable. The Australian acacias have several advantages, with rapid establishment, very high growth rates and their unpalatability to grazing animals helps them to rapidly colonise on farms or degraded land.

Weediness and suckering

There has been no evidence of "weediness" amongst the acacia species being developed. This is probably due to the dormancy of acacia seed (germination only occurs after contact with fire), any young seedlings are readily eaten by goats, high annual weeding intensity in fields with hoes that would remove any tree seedlings and the cutting/removal of any trees that grow for firewood/building timber. (Yates, 2010). None of the four acacias species under development and use appear to sucker.

Acacias for <350 mm rainfall zones

The current acacia species and provenances have been developed for 350–500 mm rainfall areas. However, diminishing and unreliable rainfall due to climate change now demands the selection of more drought tolerant provenances or new species for the 150–350 mm rainfall zones.

Seed production and inoculation

Further research is needed to understand and improve seed production and a commercial inoculant for the semi-arid acacia species would greatly improve establishment, growth rates and nitrogen fixation.

Human food

The development of Australian acacia seeds for human food has also been very slow. A small acacia seed market has increased the local demand for acacia seed. Further ongoing research is helping to identify limiting factors and strategies to build the market and so encourage more widespread planting of acacias and promotion of the FMAFS.

Key lessons for adoption

The FMAFS is an incremental advance and rides on the success of FMNR. The following factors have been vital for successful adoption by farmers and their communities:

- Winning farmers' trust. Close working relationships between SIM staff and farmers have been built for over 20 years and this liaison has helped farmers to understand the root causes of crop failure. Ongoing development activities have created a high level of trust. SIM staff members have persevered over many years in the face of misunderstanding, setbacks and even rejection.
- Regular follow-up with farmer groups at least twice every month throughout the year has enabled good continuity transfer of knowledge and problem solving. Training occurs both at the research/demonstration center and on village farms where real examples are viewed and discussed.
- Weekly radio programs have helped to reinforce the grass roots teaching and training.
- Farmer-to-farmer communication was the key to widespread adoption of FMNR and is now having impact with the FMAFS. Also important have been farmer exchange visits with motivated farmers to promote dialogue.
- Opening up a small market for acacia seed and wood, in conjunction with promotion, has helped to generate interest in the FMAFS.
- FMAFS – a set of principles. The FMAFS should be seen as an approach to, or set of principles for, sustainable agriculture. Key components include maximising biodiversity of annual and perennial species, mulching to protect soils, nitrogen fixing plants, crop rotation, animal-plant interactions, spreading risk and labour demand throughout the year. Whilst the established one and half-hectare farm layouts have been developed for initial training and promotion, these are not strict blueprints. As with FMNR, the FMAFS is flexible. The farmers themselves select the layout, the tree and annual crop species, and the degree of FMNR with the annual crops. It is critical to listen to farmers' needs and objectives and to adapt the FMAFS accordingly for particular agro-climatic conditions and the concomitant appropriate species mix.

Potential for broader application: Farm resilience and adaptation to climate change

Diminishing annual crop yields, increasing population and the global food crises now mean that the world is faced with the need for another "Green revolution". The first Green revolution more than doubled grain yields in Asia by irrigation, dwarf crop varieties, chemical pesticides and synthetic fertilisers. Recently the World Bank and United Nations (UN) Food and Agriculture Organization released the findings of a study, "Assessment of Agricultural Knowledge, Science and Technology for Development", and concluded that the immense production increases brought about by science and technology in the last 30 years (Green revolution) have failed to improve food access for many of the world's poor. The UN panel called for a paradigm shift in agriculture towards more sustainable and ecologically friendly practices that would benefit the world's 900 million small farmers. Experts see the answer in targeted breeding through genetic engineering, sustainable farming and smarter irrigation (Bourne, 2009).

A decade earlier, Rinaudo et al (2002) observed that the "green revolution" had little impact in Africa, especially in semi arid regions (<400 mm annual rainfall) and argued that a new type of green revolution was needed for Africa's drylands based on entirely new crops that are fundamentally adapted to the variability of the semi-arid environment.

"If there is to be a 'Green revolution' for the semi-arid tropics, it will have to be through plants that thrive under such conditions, yield well and require minimal inputs. Millions of third-world farmers have no access to the usual green revolution inputs. Increasingly they are farming on exhausted, marginal lands under adverse climatic conditions that are unsuitable for conventional crops. For them, a biological revolution is needed, in which plants are selected and bred to suit the prevailing environmental conditions" (Rinaudo et al 2002).

Climate change specialists predict the semi-arid regions of Africa will become warmer and drier with shorter growing seasons and increases in climatic variability (droughts and floods) (Mahe and Paturel, 2009, Maranz 2009, Salopek 2008). Annual crop yields are expected to decline by at least 15% by 2030 in the Sahelian region (150–600 mm annual rainfall) (Bourne, 2009).

A recent survey of farming families in the Maradi region showed that the average farming family experienced at least a four-month food deficit in their annual food production (Haglund et al 2011). If these poor subsistence farmers and others across the Sahelian region are to survive, then it is clear that they need to make significant changes, adopting holistic integrated and sustainable farming systems like the FMAFS which utilise new well-adapted food crops such as the edible acacias.

Now that working models have proven successful in research and farmer trials, there is no reason why the FMAFS cannot be adapted and replicated throughout other semi-arid regions. Successful replication will depend on a range of factors:

- Farmers need to recognise that their current farming system is not meeting their needs and be willing to change their traditional farming practices. They need to understand the many benefits of FMAFS and that the extra effort of establishment and care of new trees, doing FMNR, CRM and rotating crops is worthwhile. Key farmers with good FMAFS farms provide powerful examples and motivate adoption of FMAFS by other farmers.
- Farmers need training in FMNR and in tree planting, management, harvesting and processing of acacia seed.
- The extension/change agent plays a vital role in helping people understand their situation and in encouraging them to try new ideas and techniques. Empathy, persistence, skill and flexibility are key attributes.
- Well-adapted, affordable improved crop varieties and other agroforestry trees need to be made available from governments, international agencies, or NGOs. Access to research results and understanding their implementation at the farm level will help adoption of the FMAFS.
- If food security is to be attained, and sustainable farming practices followed in the marginal semi-arid regions, government extension services need to grasp the benefits of new farming systems such as the FMAFS and give credibility to adoption and get involved in their promotion.
- Government agencies also need to have favorable natural resources policies. Farmer ownership of trees and other natural resources is vital to encourage their investment in a new farming system.

- FMNR, the foundation of the FMAFS, requires the presence of coppicing tree stumps on farmers' fields and/or viable tree seed reserves in the soil. In some areas, tree stumps have been removed for mechanical agriculture. However, in most semi-arid regions of Africa there are many tree species that grow/survive from root stumps.

Conclusion

The growing humanitarian needs and consequent food aid requirements in semi-arid regions of Africa will continue in an ongoing cycle unless farming communities take responsibility for their own situations and make significant changes to restore degraded landscapes and adopt sustainable farming systems. There is now overwhelming evidence from more than two decades of research and development that edible, multi-purpose Australian acacias are ready to become a significant new food crop to combat child malnutrition, improve food security, build farm resilience and support adaptation to climate change (Harwood et al 1999, Rinaudo et al 2002, Yates 2010).

The FMAFS is a simple, teachable and easily transferable farming system that can become a significant vehicle for the widespread planting and adoption of acacias by farming communities. Research and development in the Maradi region of Niger over the last five years, together with the teaching and training of other NGOs working with farming communities gives optimism that the FMAFS have the potential to play a significant role in the new "Green revolution" for the semi-arid tropics outlined by Rinaudo et al (2002).

The FMAFS needs to be understood as a set of guiding principles for sustainable agroforestry in the semi-arid tropics with wide application to other semi-arid regions of the world. Importantly, farmers are able to manage and have control of trees on their land. Every acacia tree provides multiple benefits, biodiversity is maintained and enhanced, as the trees provide shade and habitat for beneficial animal species. The range and rotation of high-performing annual crops provide food, income and reduce the crop disease incidence that is often associated with mono-culture and continuous cropping. During periods of food shortage when crop yields are marginal, tree products can be sold to provide income and enhance food security. Moreover, crop residues provide increased fodder for animals and, instead of being burned as cooking fuel, can also be used for mulching to reduce water runoff and enhance soil fertility.

If FMNR, which is now recognised as one of the great success stories in the field of revegetation and agriculture in Africa, has spread to millions of hectares in Niger and other countries, why not FMAFS, which is an incremental advance, incorporating all the same principles and the enormous bonus of edible acacias? Importantly, as with FMNR, the FMAFS is low cost, including tree establishment (nursery and field) and the farmers' labor. Labor requirements and income generation are spread throughout the year and farm income at least doubles.

Acknowledgements

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References

Bourne, J.K. (2009). The end of plenty: The global food crises. *National Geographic*, 214, 6.

Cunningham, P. J. (2010). *The Farmer Managed Agroforestry Farming System*. ECHO Technote.

Cunningham, P.J., and Abasse, T. (2005). Domestication of Australian acacias for the Sahelian zone of West Africa. In *Domestication de especes agroforestieres au Sahel: Situation actuelle et perspectives.* (A. Kalinganire, A. Niang and A. Kone eds.), pp. 64–74. ICRAF Working paper no. 5. Nairobi. World Agroforestry Centre.

Cunningham, P.J., Nicholson, C., Yaou, S., Rinaudo, T. and Harwood, C. (2011). *Utilization of Australian acacias for improving food security and environmental sustainability in the Sahel, West Africa* (In prep) Agroforestry Systems.

Haglund, E., Ndjeunga, J., Snook, L. and Pasternak, D. (2011). Dry land tree management for improved household livelihoods: Farmer managed natural regeneration in Niger. *Journal of Environmental Management,* 92, 1696–1702.

Harwood, C.E., Rinaudo, T. and Adewusi, S. (1999). Developing Australian acacia seeds as a human food for the Sahel. *Unasylva,* 196, 57–64.

Mahe, G. and Paturel, J. (2009). 1896-2006 Sahelian annual rainfall variability and runoff increase in Sahelian rivers. *Geoscience*, 341, 583–546.

Maranz, (2009). Tree mortality in the Sahel indicates an anthropogenic ecosystem displaced by climate change. *Journal of Biogeography*, 36, 1181–1193.

MIDP Technical Manual (2002). *Rural Community Development Methodologies of the Maradi Integrated Development Project 1984-2001,* Maradi, Republic of Niger, West Africa. (A. Rinaudo, J Matthews, A Strong, R Perkins and T. Dickens eds), pp. 108.

Pasternak, D., Nikiema, A., Fatondji, D., Ndjeunga, J., Koala, S., Dan Goma, A. and Abasse, T. (2005). The Sahelian eco-farm. In *Proceedings of the International Symposium for Sustainable Dryland Agriculture Systems.* (G. Omanya and D. Pasternak eds), pp. 286–296. 2-5 December 2003, ICRISAT, Niamey.

Rinaudo, A. (2007). The development of Farmer Managed Natural Regeneration. *Leisa Magazine*, 23.2, 1–8.

Rinaudo, A. and Cunningham, P. (2008). Australian Acacias as multi-purpose agroforestry species in semi-arid regions of Africa. *Muelleria*, 26, 79-85.

Rinaudo, A., Patel, L. and Thompson, L. (2002). Potential of Australian Acacias in combating hunger in semi-arid lands. *Conservation Science,* 4, 161–169.

Salopec, P. (2008). Lost in the Sahel. *National Geographic,* 213.4, 34–67.

Yates, P. (2010). *Australian Acacias. The potential to combat child malnutrition, build agricultural resilience and support adaptation to climate change in semi-arid Africa.* Report on a research project in partnership with World Vision Australia. pp. 76.

Wattle happen without water?

Australian acacias for lower rainfall zones (<350 mm) in the arid tropics

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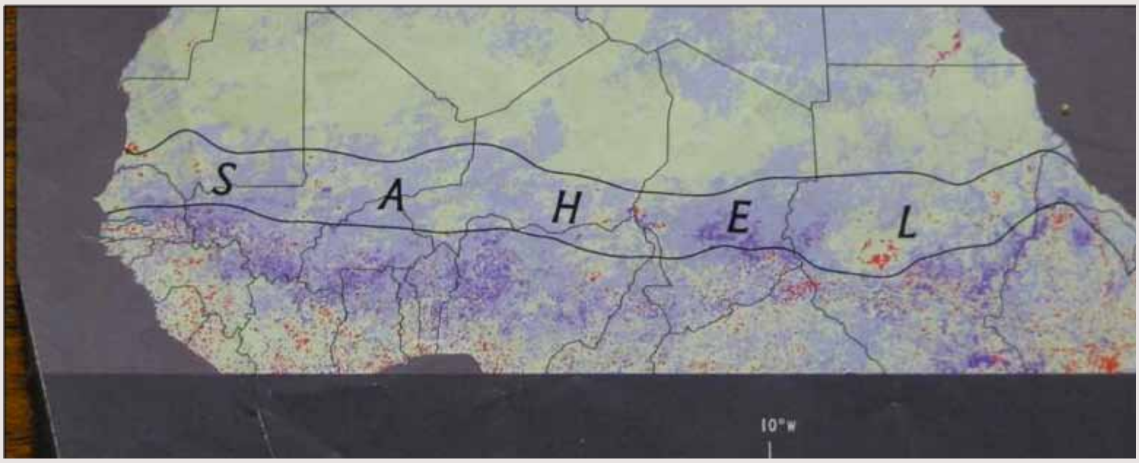
This is edited from Peter's additional presentation at the workshop

Introduction

There is a growing need to evaluate Australian acacias for lower rainfall zones (<350 mm annual rainfall) in the arid tropics. Whilst I have limited knowledge of this group of acacias, the main purpose of this paper is to share some background on this topic, the key attributes we might be looking for in the lower-rainfall acacias, and some strategies for developing the target species with potential candidates.

Figure 1: The Sahelian zone of West Africa. 150–600 mm annual rainfall.



The Sahelian zone and climate change

The Sahelian zone in West Africa has moved south over the last 40 years. Climate experts now predict that this region can generally expect warmer, drier conditions with reduced growing conditions and higher climatic variability. Annual crop production is expected to be reduced by approximately 15 per cent over the next 20 years.

There has certainly been significant climate change with more frequent famines (1984, 1988, 1990, 1994, 1998, 2005, 2010) in the Maradi region over the last 30 years. Data from the 1960s and 1970s showed that Maradi had an average annual rainfall of 609 mm. In the last 10 years there have been two complete crop failures in most of the region (Fig 2). The average annual rainfall at Maradi is now 450 mm. This amounts to a 26% reduction. We are generally finding fewer high-intensity rainfall events with longer gaps between the rains. If there is a gap of more than 20–22 days between rainfall events, annual crops will fail and not recover.

Figure 2: Sorghum crop failure 2005

Millet crop failure 2008

Dry zone acacia species and provenances evaluated in the Sahel

There have been numerous species and provenance evaluations of Australian acacias in the Sahel (Fig 3). In the 1970s there were valuations of these dry zone acacias for potential of fuel wood and environmental protection; and in the 1980s there were species and provenance trials in North Cameroon, Burkina Faso and Niger. It should be noted that all these sites were in the Sudano–Sahelian zone (>600 mm annual rainfall) and not strictly the Sahel. Even in this more favourable environment, the adaptability of the species trialled was generally poor with a less than 50 per cent survival rate over three years. In the trials at Maradi and Danja, the inland-lower rainfall *Acacia colei* was the stand-out performer for growth rate, wood and consistent seed production.

Figure 3: Dry-zone acacia species and provenances evaluated in the Sahel

1970s – *A. colei*, *A. holosericea* – potential fuelwood, environmental protection

1985-86 Species trials:
North Cameroon 24 Acacia spps (30 provenances)
Burkina Faso, Niger 9 acacia spps.

Provenances trials:
A. colei (8), *A. holosericea*, (1) *A.cowleana* (11)
Other acacia sps (22) – 31 provenances.

Trials at 3 locations:

Niger (N'dounga) 600 mm rainfall

Burkina Faso (Gonse) 750 mm

(Djido) 600 mm

Domestication of Australian acacias by SIM

In the 1990s the Maradi Integrated Development Project (MIDP) team, led by Tony completed various acacia species provenance trials and nutritional evaluations on *A. colei* and *A. tumida*. *A.colei* was widely promoted through food for work programs. Over the last 10 years there has been a re-evaluation of a broader range of *A. torulosa* and *A. tumida* provenances with the aim of overcoming some of the limitations in *A. colei*. A range of acacias have subsequently been domesticated (Table 1).

Table 1. Domestication of Australian acacias by SIM, Maradi 2001–2010

Species	Variety	Years	Rainfall adaptation
A. colei	Ileocarpa (2)	1990–2008	400–550 mm
A.torulosa	Tall	2002–8	400–600 mm
	Branching (Elliot)	2002–8	400–600 mm
	Wycliffe well	2008–10	300-450 mm
A. tumida	Kulparn	2006–8	400–550 mm
	Kulparn (Sadore)	2009	500–650 mm
	Tumida (tall)	2006–2008	400–550 mm
A.elacantha	Branching (5)	2008…	400–550+ mm

Average rainfall has decreased significantly in the years 2002–2009 at Danja resulting in low or no seed production when the rainfall was less than 400 mm. The current list of domesticated acacia species are not considered adequate if rainfall continues to diminish. There is a strong case for the selection and development of species that are productive with less than 350 mm annual rainfall.

More consistent seed production in lower rainfall years has been achieved with *A. torulosa* through within provenance selection, but there are still significant limitations.

If multi-purpose Australian acacias are going to make impact in this needy region of the Sahel there will need to be a new set of field trials and new species evaluated. One new provenance of *A. torulosa* from Wycliffe Well (350 mm rainfall) is performing well but measurements on seed production in lower rainfall years are still being measured. In north-west Niger, the Samaritan's Purse project has been trying to grow *A. colei* in degraded areas but faces many challenges, including goats, security and a harsh environment with 250 mm annual rainfall.

Key attributes for lower rainfall acacias

In the process of determining appropriate acacia species for <350 mm rainfall zones, the following key attributes are suggested as essential:

- broad adaptation to 250–350 mm annual
- rainfall (arid tropics)
- ease of propagation from seed (tree nursery)
- rapid growth
- multi-purpose potential
  - firewood
  - seed (high nutritive value/taste)
  - fodder
  - land rehabilitation

- good consistent seed production
- coppicing/non-suckering

Strategies for identifying target species

Some of the proposed strategies for identifying these target species are given below and include:

- bio-climate and/or bio-landscape matching
- species from arid tropics – central northern Australia, Pilbara, WA
- seedlots and provenances from collections (ATSC)
- other collections
- local knowledge
- shortlist species/provenances
- targeted seed collections
- evaluations in regions where acacias are grown

Potential target species

Further discussions with Bruce Maslin and Jock Morse have led to a list of potential target species (Table 2). Targeted collections will begin in October 2011 and a further collection will occur in 2012 and include the Pilbara region of Western Australia. Whilst provenances of *A. murrayana* and *A. jennerae* will be collected, there will need to be extreme care in evaluations; both these species were observed to be highly suckering in their lower rainfall habitats, so may carry a high risk of weediness.

Consideration should also be given to the inoculation requirements of these species. Discussions have been initiated with the CSIRO for collaborative research and soil samples for Rhizobium capture are being taken during collections trips to isolate suitable Rhizobium from the naturally occurring host species.

Table 2: Potential acacia species for lower rainfall (<350 mm) zones

Acacia species	Comments
A. fecunda	
A. adsurgens	
A. ammobia	
A. aneura (var tenuis)	
A. colei	Lower rainfall margins
A. cowleana	
A. dictyophlebia	
A. elachantha	
A. jennerae	
A. laccata	
A. melleodora	
A. murrayana	
A. sabulosa	
A. tumida (var pilbarensis)	In Pilbara
A. torulosa	Lower rainfall margins
A. validinervia	
A. victoriae	
A. undoolyana	
A. thomsonii	

Results of Acacia saligna growing in Chile and exploration of new food products

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1. Introduction

In Chile there is only one species of the genus, *Acacia caven* that is distributed as sclerophyllous forest from Atacama (27° 18') to the Bío-Bío Region (36° 47') and also exist in Argentina, Uruguay, southern Brazil, Paraguay and Bolivia.

Acacia species introduction in Chile, *A. melanoxylon, A. dealbata, A. decurrens, A. armata* and *A. eburnea,* date since 1908 with the afforestation work of Federico Albert for erosion control in a coastal dune area of Chanco.

In 1960 *A. saligna,* known as *cyanophylla,* was introduced with the same purpose in the Region of Coquimbo.

In 1983 other acacia species were introduced by the project CONAF (Forest Service of Chile)/ UNDP/FAO. However these studies were discontinued due to alterations in experimental trials due to damage by animals (goats, rabbits and hares).

The introduced species in the semiarid region included: *A. aneura, A. brachybotya, A. capensis, A. cyclops, A. dealbata, A. decurrens, A. dietrichiana, A, distachya, A. farnesiana, A. hakeoides, A. longifolia, A. pendula, A. primocarpa, A. radianna, A. retinoides, A. salicina, A. semperflorens, A. senegal, A. tortilis, A. victoriae.*

In addition to the plantations of *A. saligna* in the semiarid zone of Chile, other species of potential commercial and industrial interest with requirements of higher rainfall (600 to 1500 mm per year) are being investigated by INFOR. Research projects include silviculture, genetic improvement and utilisation of timber for *A. melanoxylon*, *A. dealbata* and *A. mearnsii,* whose main purposes are productive lumber, pulp and paper boards, tannin leather and other products (Pinilla et al, 2010).

Figure 1: Experimental plot of *A. dealbata* in the cool temperate zone of Chile (Pinilla et al, 2010)

Silvicultural management of *A. dealbata* and *A. melanoxylon* has been very careful because of the potential of these species as an invader with all the associated economic and ecological risks.

In recent decades, and as a result of various research projects with *A. saligna* (CORFO, CONAF, INFOR), in the semi-arid zone of Chile (Region of Coquimbo), reforestation programs were developed for the recovery of degraded soils, forage production for livestock and fuelwood production (Perret and Mora, 2000).

The plantations were also extended as a result of Decree Law 701 promulgated by the State of Chile in 1974 that subsidised up to 75% of the cost of establishing forest plantations. Thus 15,659 hectares were planted (INFOR, 2010). This document summarises the main findings of the cultivation of the species and the exploration of new food uses.

2. Objective

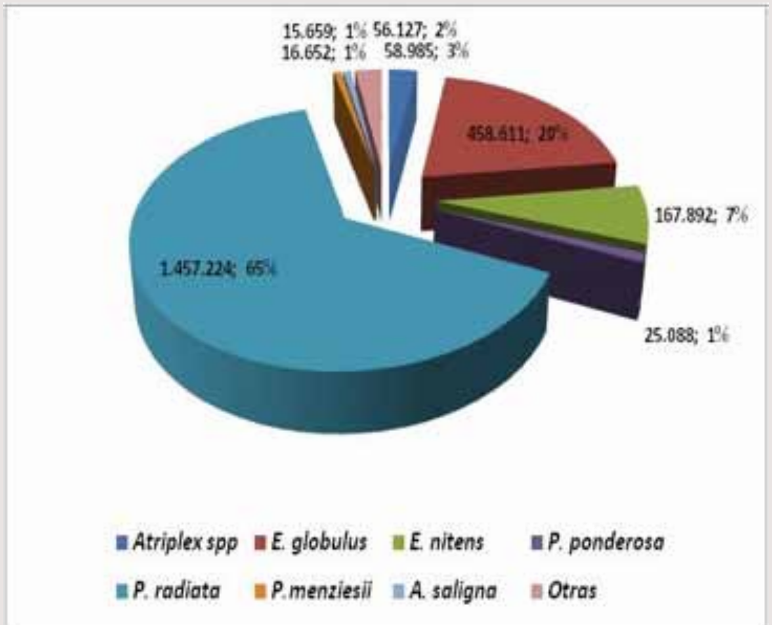
The aim of this paper is to summarise the main results obtained with the introduction of *Acacia saligna* in the semiarid areas of Chile, mainly in the Region of Coquimbo, and exploration of new productive applications related to the use of seeds for human food.

3. Area of forest plantations in Chile

In recent decades the area planted with fast-growing exotic species in Chile have increased significantly for the production of solid wood and pulp and paper.

At present, of the country's total area, 16,595,332 hectares are covered with forests, of which 2,256,238 hectares correspond to fast-growing exotic species.

Figure 2: Area of forest plantations in Chile (INFOR, 2009)



The main coniferous species are *Pinus radiata* (1,457,224 ha) *Pinus ponderosa* (25,088 ha) and *Pseudotzuga mensiesii* (16,652 ha). The principal hardwood species are *Eucalyptus globulus* (458,611 ha) and *E. nitens* (167,892 ha).

4. The importance of Acacia saligna in the Region of Coquimbo for rural communities

Most plantations in semiarid areas consist of *A. triplex spp* and *A. saligna* (Region of Coquimbo) to restore degraded soils and combate desertification.

Figure 3: Plantation area of *Acacia saligna* in the Region of Coquimbo (INFOR, 2009)

COMUNA	ATRIPLEX SPP.	ACACIA SALIGNA	E. GLOBULUS	OTRAS	TOTAL
La Serena	7,0	379,3	488,7	748,9	1.623,9
La Higuera	38,9	337,1	19,5	13,1	408,5
Coquimbo	11.976,8	4.153,5	302,3	432,3	16.864,9
Andacollo	255,0	6,8	8,4	223,1	493,3
Vicuña	4,2	4,2	46,3	39,9	94,6
Paiguano	0,0	0,8	0,0	2,6	3,4
Prov. Elqui	12.281,9	4.881,8	865,2	1.459,8	19.488,6
Ovalle	13.920,9	5.661,3	822,6	585,7	20.990,5
Monte Patria	452,5		141,8	1.212,2	1.806,5
Punitaqui	989,6	462,2	94,1	204,3	1.750,2
Combarbalá	214,4	113,2	8,7	200,4	536,6
Río Hurtado	60,5	54,4	31,4	54,2	200,5
Prov. Limarí	15.637,9	6.291,0	1.098,6	2.256,8	25.284,3
Illapel	2.991,8	626,5	169,9	309,7	4.097,9
Salamanca	1,4	58,8	28,9	123,4	212,5
Los Vilos	12.139,5	652,8	362,8	449,1	13.604,3
Mincha	15.933,3	3.148,1	89,4	1.262,9	20.433,7
Prov. Choapa	31.066,0	4.486,3	651,0	2.145,1	38.348,4
Total	58.985,8	15.659,0	2.614,7	5.861,7	83.121,2

The species *A. saligna* is considered a forest resource of recognised competence in the establishment of agroforestry systems (Hnatiuk and Maslin, 1988; McDonald and Maslin, 2000). It has become the tree species of greatest interest in the Region of Coquimbo, due to their adaptation to adverse environmental conditions such as drought and salinity with favourable results of survival and growth to ensure its sustainability over time.

Figure 4: Plantations of *A. saligna* in the Region of Coquimbo

The species has been used by "Comuneros" in the rural communities of this region as supplementary fodder for animals, especially goats. Leguminous species can fix atmospheric nitrogen, enriching the naturally degraded soil and do not require irrigation for cultivation except when supporting the establishment of the plantation.

There are large variations in the nutritional value of fodder, probably due to its genetic variability among subspecies (Sullivan, W, 2005 personal communication). The genetic origin of the Chilean local race *A. saligna* is unknown.

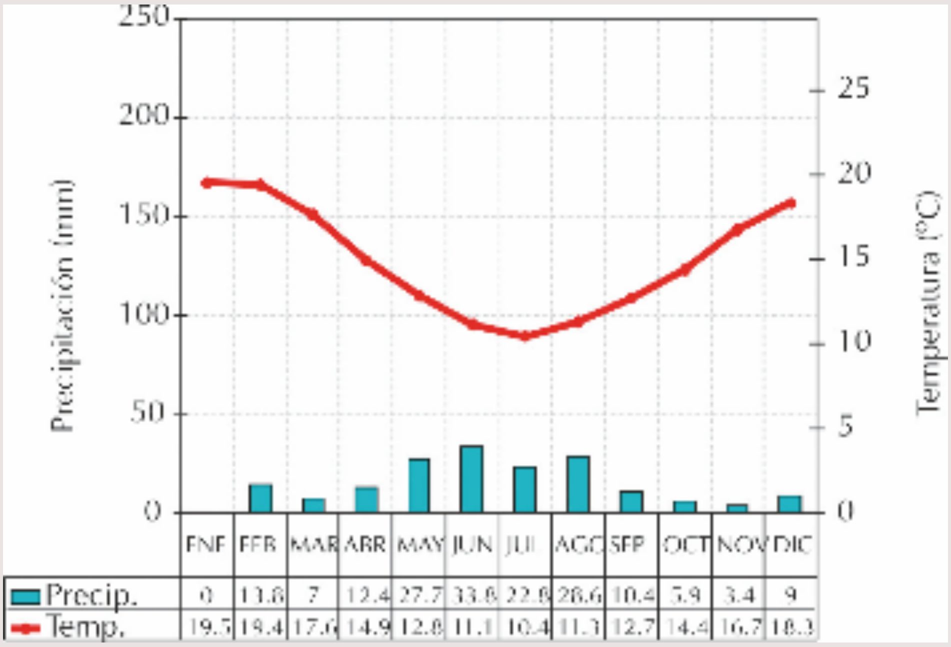
In rural areas there are differences of agriculture practices and size of producers for legal and tax regimes. The small farmer is one who operates an area not exceeding 12 irrigated hectares or having an area less than 200 hectares and whose assets do not exceed the equivalent to annual 3,500 UF (around US$164,000) and their income comes mainly from the farm by working the land themselves, whatever their tenure.

A farmer is a person who lives and works in the field, whose revenue comes primarily from agricultural and forestry activities conducted in person, whatever the legal status that exists, as long as their economic conditions do not exceed those of a small agricultural producer and the work is done by people within their families (National Congress Library, 2004).

"Comuneros" are a group of land owners in which the number of the community far exceeds the capacity of the land, as it does not meet the basic subsistence needs of their owners and family groups (Gatica and Perret, 1999).

The Coquimbo area is characterised by prolonged periods of drought, saline soils and accelerated desertification processes (Holmgren et al., 2006).

Figure 5. Ombrothermal graphic of Ovalle, Coquimbo Region



Rainfall is concentrated during the winter, with average annual values of between 100 mm and 260 mm. Every few years there is high-intensity rainfall and a high quantity of rainfall. This factor is of importance to forestry and agricultural activities in the area, since water availability is low compared to the high demand for it (MABChile Committee, 2003). The main results of diagnosis research done in rural communities in the Region of Coquimbo (Gomez, 2004) concluded that:

(a) the plantations of *A. saligna* were not planned properly for a productive purpose and they have no silvicultural management;

(b) planting sites chosen were not optimal, which influenced mortality and plant growing;

(c) smallholders have a low educational level and there is no motivation to learn more about the potential of plantations of acacia.

4.1 Silviculture oriented for goats fodder

The productive objectives of *A. saligna* plantings in rural areas are essentially as a supplementary food in an emergency such as in prolonged periods of drought, shade for the goats and as protection and to stabilise degraded soils. These unique properties make the cultivation of the species attractive for the small owner and also for large scale (Hassan, 1997; Perret and Mora, 2000).

Unlike traditional forestry where pruning is primarily intended for the production of high quality wood, in drylands pruning develops the architecture of trees or shrubs for the objective of forage production for livestock (Vita, 1997). The incorporation of silvicultural treatments such as pruning and thinning improves crop productivity. Control of the height of growth through shrubbery cuttings, increased availability of fodder for grazing animals.

Managing the crop for fodder purposes can be accomplished by direct harvesting of crop foliage, handled with a stump of 25 to 50 cm after the third year, or as a topping when they have reached two meters in height. The intervention must be done in the period before the summer growth (Serra, 1997). Bratti (1996) concluded that the trees cut down to 50 cms height had a statistical difference in vigor and growth compared with other cutting heights.

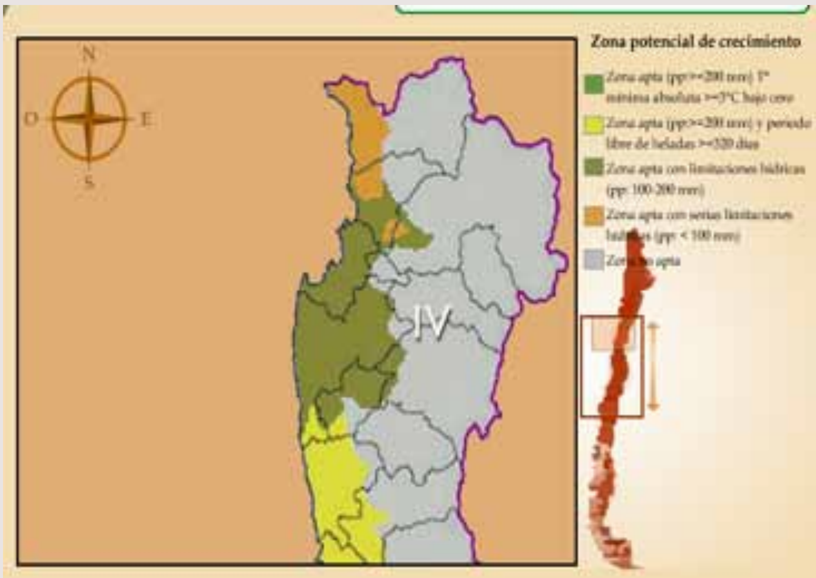
4.2 Potential areas for Acacia saligna plantations in Chile

A. saligna is a multipurpose species (Valdebenito et. al., 1995, Maslin and McDonald, 2002 and WAFLA, 2006) which can be used for the following purposes:

a) afforestation on saline soils
b) phytoremediation of soils contaminated by mining waste
c) stabilisation of degraded soils and erosion control
d) shade and fodder for animals
e) bioenergy
f) ornamental tree
g) a major source of tannin and secretions of bark gum (27%) that contain urolic acid for the food industry
i) seeds as a food source

INFOR has developed software (www.gestionforestal.cl) for small and medium landowners that match the ecological requirements of the species with soils and climate information of agro-climatic districts and that permit the selection of areas of potential growth of the species in the Region of Coquimbo. The grouping system in potential areas, considered critical climatic elements in relation to their temporal and spatial distribution, both of which have great effect on the development of vegetation.

Figure 6: Potential areas of growth for *A. saligna* in the Region of Coquimbo. Forest Management System Project for the Modernisation of Small Farmers (INFOR, 1999)



According to the selection of potential sites using the software, *A. saligna* has potential for development in both the coast and interior of the Coquimbo Region to an altitude of about 1000 metres, with an estimated area of 415,129 hectares of reforestation in the province of Elqui (Urquieta et al., 2000).

4.3 Growth and seed yield on dry land plantations

Acacia saligna is considered a fast-growing species, reaching 8 metres in 4 to 5 years of planting in sites with few limitations. In studies of irrigated plantations in northern Chile there was an average annual increase in height from 30–71 cm. Its growth is lower in conditions of prolonged drought, so their production is variable reaching between 1.5 to 10 m^3 according to site conditions in rotations of 5 to 10 years and sprout management.

Experimental plots established by INFOR in dry land areas of the province of Choapa showed that forage production may reach a value between 0.8 and 2.2 tons/ha of dry forage at 3 and 4 years after planting (Perret and Mora, 1999). McDonald et al. (2002) mentioned that seed yields found in a plantation of *A. saligna* have varied between 54 and 170 kg seed/ha. *Acacia saligna* in Chile began to produce seeds at 5–6 years.

4.4 Australian genetic populations represented in Chile

According MacDonnald (2007)[1] the most common form of *A. saligna* present in the Region of Coquimbo corresponds to *A. saligna* subsp. *pruinescens*, which has shown great sprouting, survival and growth. Pruned plants produce abundant shoots and a prolific amount of foliage that can be eaten by livestock during the driest season.

Figure 7: Typical form *pruinescens* represented on *A. saligna* plantations in the Coquimbo Region (Photo Maurice McDonald)

4.5 Provenance trials of A. saligna in Chile

Genetic variability present in *A. saligna* is a key factor to improving survival and productivity in periods of drought (George et al., 2006; Mora and Meneses, 2004).

SEEDLOT	LOCATION	LAT	LONG	ALT
P1-17971	Ravensthorpe 1	33° 35′	120° 08′	150
P2-15193	Kelmscott	32° 07′	116° 02′	150
P3-15789	Sanford River	27° 20′	116° 24′	320
P4-15791	Greenough River	28° 42′	115° 02′	175
P5-15794	Geraldton	28° 35′	114° 37′	200
P6-15795	Murchison River	27° 51′	114° 37′	180
P7-15797	Mingenew	29° 12′	115° 26′	180
P8-15798	Lake Indoon	29° 52′	115° 39′	100
P9-15800	Moora	30° 34′	116° 01′	200
P10-15803	Muntadgin Rock	31° 45′	118° 35′	320
P11-15806	Lake Muir	34° 26′	116° 40′	170
P12-15810	Boyatup Hill	33° 14′	123° 02′	183
P13-15822	Lancelin	31° 01′	115° 20′	10
P14-15828	Ravensthorpe 2	33° 35′	120° 03′	234

[1]Revista Ciencia e Investigación Forestal (INFOR, 2007)

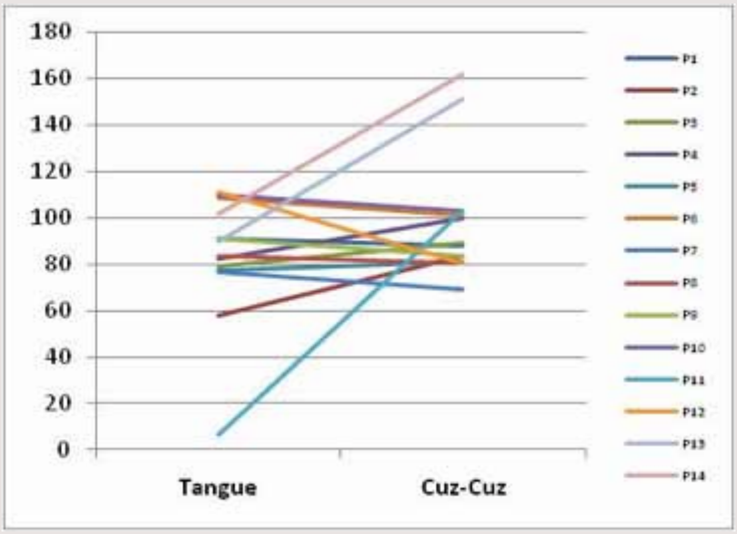
The establishment of provenance and progeny trials is the first step in a tree breeding program. In 1999 two provenance trials of *A. saligna* were planted in two sites of the

Coquimbo region: El Tangue (30° 45’–71° 47’) with 130 mm precipitation, and Cuz-Cuz (31° 63’–71° 22’) with 244 mm annual precipitation.

Figure 8: Australian provenances tested in the Coquimbo Region

The average growth in height to 15 months in the provenances, varied between the two sites, showing better growth in the trial at Cuz-Cuz, located in the southern part of the region. The best sources in both places were Ravensthorpe (P14) and Lancelin (P13).

Figure 9: Site x provenance interaction between two trials at 15 months. Average height in cms (Adapted from Mora, 2004)



The genetic correlation values indicate a strong interaction GXE. It should be noted that the assessment was carried out at a stage in which competition between plants and/or origins was not present.

However the magnitude of interaction suggests that groups of seed sources specific to each site should be selected, as not always the best group for a specific site maintained their superiority at the other site.

5. Exploration of new food products from Acacia saligna seed (R & D INFOR project with CREAS/Universidad de Santiago de Chile)

The use of the acacia seeds as food for human consumption is one of the most interesting positions of the research and development that is investigated by INFOR with other technological centres in Chile.

It is well known that acacia seeds are edible and have been used historically as a protein source for Aboriginal people in Australia, in the production of flour and are integral to the industry of the bushfood in Australia, market of functional natural products with beneficial properties for health as the content of fibre of their meal and its low content glycaemic.

Figure 10: seeds of acacia species inside the pods

Acacia seeds have been identified as one of the 10 most commercial forestry food products (Graham and Hart 1998) and its many potential industrial uses include: flavouring of sauces and icecream, a substitute for coffee, flour to be used in breads, biscuits and pastas, ingredients in cosmetics and soaps and food for animals.

According to Rinaudo et.al. (2002) acacia seeds processed into flour does not suffer abrupt changes in its nutritional composition. The authors studied the behaviour of the seeds of *A. colei*, when transformed into flour. It did not lose the nutritious quality of the seed in the process of transformation, with loses of only 12.9% of protein and 2% carbohydrates, while increasing crude fibre by 61.4%.

Figure 11: Results obtained from the nutritional analysis of the seeds of *Acacia saligna* for human food purposes

Caracteristica	Valor	Fuente	Comentarios
Proteina total % por masa	21.78 20.6 23.00	Ruinaldo (2011) USACH (2011) Yates (2010)	 (%Nx5,30) Promedio 26 spp
Calorías (Kcal/100 grs)	331	USACH (2011)	
Carbohidratos disponibles (%)	26.0	Yates (2010)	Promedio 26 app
Fibra (%)	32.0 12.3	Yates (2010) USACH (2011)	Promedio 26 spp Fibra cruda
Lipidos %	6.7	USACH (2011)	
Grasas % por masa	11.06	Ruinaldo (2011)	
Total cenizas % por masa	3.29 4.70	Ruinaldo (2011) USACH (2011)	
Calcio gr/kg	3.71	Ruinaldo (2011)	
E.N.N.(%)	47.0	USACH (2011)	
Fierro gr/kg	0.05	Ruinaldo (2011)	
Manganesio gr/kg	0.04	Ruinaldo (2011)	
Magnesio gr/kg	2.78	Ruinaldo (2011)	
Potasio gr/kg	10.06	Ruinaldo (2011)	
Fósforo gr/kg	1.16	Ruinaldo (2011)	
Zinc gr/kg	0.03	Ruinaldo (2011)	

The project's main objective is to improve the profitability of existing plantations of *Acacia saligna* in the dry zone of the central north of Chile, incorporating new products like differentiated flours with functional value.

For this the R & D will assess the nutritional and functional value of the seeds of *A. saligna* and other species of the same genus. A protocol and prototypes of different flours for the market for functional foods will be investigated.

Mixed flour will be low on the glycaemic index, gluten-free, and the starch content will be increased using a biotechnological process. It is well known that the seeds of acacia spp. and other edible indigenous products are part of the "bushfoods" market in Australia. The seeds are extremely nutritious, containing several times the protein levels of that found in wheat.

As expected outputs of the technological project are: (a) to assess the nutritional value of the seeds of *A. saligna*, (b) to assess the technical and economic feasibility of producing flour with seeds of *Acacia saligna*.

6. Conclusions

- There are 15.659 hectares of *A. saligna* planted in Chile and an estimated potential area of reforestation of 415,129 hectares in the province of Elqui (Coquimbo Region).
- The foliage is used as a supplementary food or emergency fodder in prolonged periods of drought, shade for livestock and as protection and for stabilisation of degraded soils.
- *A. saligna* is considered a fast-growing species for dry lands, reaching 8 metres in height 4 to 5 years after planting in sites with few constraints.
- In trials in dry land in the north of Chile, acacia has an average annual increase in height of 30–71 cm.
- Production is variable, reaching between 1.5 to 10 m^3 per hectare according to conditions of the site rotations of 5 to 10 years and coppice management.
- The production of forage can be a value between 0.8 and 2.2 tonnes/hectare of dry forage often 3 to 4 years after planting.
- Returns found in a plantation of *A. saligna* have varied between 54 and 170 kg seed per hectare.
- The most common form of *A. saligna* present in the Coquimbo region would correspond to *A. saligna* subsp. *pruinescens*, which has demonstrated excellent adaptability, survival and growth.
- The best results in survival and growth in two trials of Australian provenances in the Region of Coquimbo were Ravensthorpe and Lancelin.
- INFOR CREAS/USACH and a food company are applying for funding for an R & D project to assess the nutritional value of the seeds of *A. saligna* and the technical and economic feasibility of producing flour with functional value for heath.

7. Bibliographic references

Freddy Mora Poblete, Raúl Meneses Rojas, Ciência Florestal, Santa Maria, v. 14, n. 1, p. 103–109 103. ISSN 0103-9954. *Comportamiento de Procedencias de Acacia saligna* (Labill.) H. L. Wendl. En la región de Comquimbo, Chile.

Catalina Lorna Gómez Pierotic, Santiago, Chile (2004). Universidad de Chile, Facultad de Ciencias Forestales. *Propuesta Para el Uso de Acacia saligna en sistemas de producción de Pequeños Propietarios de la Provincia de Elqui, IV Region*.

Pinilla et al, (2010). *Avances en la investigación con especies del género Acacia en Chile*. INFOR-INNOVA CORFO. Informe Técnico N° 179

Jorge Mauricio Bratti Retamal. *Efecto de la altura de corte en el rebrote de Acacia saligna (Labill.)* Wendl. Universidad de Chile, 1996. Fac. de Cs. Forestales.

Yates, P. (2010). *Australian Acacias*. Charles Darwin University

FAO, (1997). Especies arbóreas y arbustivas para las zonas áridas y semiáridas de América Latina. Serie Zonas Aridas y Semiáridas de América Latina.

Piña Cortez, Leticia, (1999). *Antecedentes sobre especies promisorias para la forestación de las zonas áridas y semiáridas de Chile*. Tesis Universidad de Concepción, Facultad de Ciencias Forestales.

INFOR, (2007). *Ciencia e Investigación Forestal. Silvicultura y Utilización de Especies del Género Acacia.* Instituto Forestal, Chile.

The chicken and the egg: What is required for the scale-up of production and consumption of acacia food products and other uses in the market place in developing countries, particularly in Tigray, Ethiopia?

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Introduction

Understanding the market for acacia is one of the first tasks necessary to provide a basis for scaling up acacia consumption and production. Market visits in Tigray where acacia is mainly produced revealed that there is no acacia currently being sold for human consumption. This observation means that a scale-up strategy would effectively require a new product to be promoted to consumers as a possible food source.

Research with acacia producers was conducted over a 7-day period, between 17 and 24 July 2011. In-depth interviews were undertaken with acacia producers, community leaders, farmers, government office representatives and NGOs. This research revealed that the

community has significant knowledge about the various uses of the plant; however their knowledge was very limited in terms of acacias use for human consumption. Peter Yates confirmed this finding in his research paper and stated “The situation in Tigray, Ethiopia is very different to that in Niger. Whereas in Niger, much work has been completed on species and provenances, and on introducing acacia foods to the community, in Tigray relatively little is known about the productive potential of *Acacia saligna* and the variations between provenances, and there is absolutely no knowledge in the community as to the food value of the seed” (Australian Acacia, 2010).

The discussions made with community members and leaders on the use of acacia and its future in the region was very informative. The people of Tigray have significant knowledge about the plant except that they do not know that the plant is good for food. A small number have heard about the use of acacia seed as human food but the majority do not have information about it.

Tigrayans know acacia is excellent for animal feed, fuel wood, building materials, and farm tools. They know also that the plant is drought resistant and good for soil and water conservation measure. It is important to capitalise on their knowledge and include it in the scaling up recommendation that this plant should be promoted aggressively so that farmers can use this plant for the aforementioned purposes. Emphasis should be given to promote acacia as human food, a message that has not yet been communicated widely in Tigray.

The main objective of this paper is to outline possibilities for the promotion of acacia as food for human consumption as well as the multipurpose use of acacia seed amongst Tigray people. Scaling up methods and recommendations are also included. The discussion will also identify the opportunities to be exploited and challenges that the project will face.

Types of acacia trees in the region

Amongst the people in Tigray, it is believed that there are many types of acacia trees but the specific types are largely unknown in the region. However, according to the farmers in the region they have classified the tree into two, based on the type of leaf and appearance. Some of the trees have narrow and long leaves while the others have relatively broad and short leaves. Sometimes Tigrayans also classify the tree based on the taste and preference of their animals towards the plant. The tree with the broad leaf is not as preferable for animals to eat. The narrow-leafed tree is more appealing for animals to eat at any time, while the broad-leafed tree can only be eaten when it is dry, crushed and mixed with other feeds. The Tigray Agriculture Research Institute (TARI) is working on identifying the type of acacia species in the region. It will be then easy to release the type and their use at different localities within the region. It has been understood that there are many acacia plants throughout Tigray with *Acacia saligna* known to be one of the main varieties. Peter Yates has also mentioned this in his research document as “The existence of many millions of *Acacia saligna* in the arid mountains of Tigrai, Ethiopia offers the possibility that similar programs could be developed in that region as are recommended for the Sahel” (Australian Acacia 2010).

Uses of acacia in Tigray, Ethiopia

Different literature suggests that acacia has many uses in dry parts of Africa. The dominant uses of acacia include a food security asset in food deficit months, restoration of highly degraded areas, feed and forage for animals, construction materials, farm tools, and income generation.

Acacia for human food

Ethiopia is one of least developed countries in the world, and is mainly dependent on agricultural production. Agriculture is the mainstay of the economy contributing for 50% of the Gross National Product (GNP), 80% of the exports and 85% of the workforce (Atsbi ADP design document 2007).

The agricultural sector suffers from frequent drought, over-utilisation of farmland and poor farming practices. The practice in Tigray is largely smallholder based, characterised by traditional use of hand tools and farm oxen. Moreover, it is highly constrained due to infertile and eroded soil that has been cultivated for centuries without any appropriate conservation methods.

Due to these factors, there are always food deficit months in the region. One mechanism to address this issue is to adapt acacia seed as food for the area. The most promising point with this idea is that the seeds are ready at the time of the food deficit months and they can easily be stored for a longer period. As per the discussions made with the farmers of the local area, acacia has many unique characters among which its season of harvesting is different from the other products in the area, and its multipurpose use. Tigray Agricultural Research Institution has collected more than five quintals (500kg) of seed for next year to conduct research on acacia's use for human food. In their estimates obtained from individual farmers, they found that one medium tree can produce 5–6kgs of seed.

Acacia seed as human food in the region is not yet accepted, except as a trial in the Tigray Agricultural Research Institution. Whilst this is the case, interviews with different acacia growers in the selected sites revealed that they have positive attitude towards the seed as human food. Their basic argument is that they have already tested the tree as feed for their animals and they found that their animals prefer the plant to any other feed. It is also noted that monkeys are more interested in the seed rather than the leaves. Growers shared that whenever they feed their animals with the leaf of the plant, it is difficult for them to shift to another feed easily. Therefore, growers know that there is no side effect for their animals and suggested that if they know that the seed and tree is good for the animals, then perhaps it would also be suitable for human consumption. This curiosity with the seed as a food source needs to be leveraged in communication and promotional messages that centre on the potential of the seed to provide food in deficit months.

Acacia for animal feed

Mixed farming consists of rearing animals and producing agricultural crops. Animal feed is the most difficult task for the farmers in the area. Farmers have adapted acacia leaf as a feed for animals and have found that camels, sheep, goats and cattle prefer acacia leaf more than any other trees in the area.

It is also important for bees. It is important because its flowering season is different from the other flowers that they use for their feed. It flowers during the dry season when the other trees stops flowering.

Honey in Tigray is scarce and expensive. It would be very important to capitalise this opportunity through organising and strengthening honey producing farmers groups in the closure areas where acacia trees have been planted.

The farmers have also identified that acacia is excellent for fattening and dairy production. They mix acacia leaf with the by-products of the local beer called "Hatela". It is very important

also to engage farmers in such kinds of income-generating activities through linking them to the closure areas.

Acacia for fuel wood

Cooking in Tigray is done with dried cow dung and wood. The price of wood for cooking is expensive as it is very restricted to bring it to market and it is very rare to find. Cow dung is not commonly found in the market. In the rural parts of the region, cow dung is common to cook "enjera" which is the dominant food for most of the people. As per interview discussions, one particular respondent said that to use cow dung for cooking is difficult because its smoke negatively affects health and also the foul odour. The respondent also shared that it is very difficult to find wood for fuel and it is very expensive and unaffordable. This respondent also said that acacia wood is very good and suitable for fuel as it has a good odour, burns for a long time with a strong flame and can also produce charcoal for use at another time. This is a strong indication of the potential for acacia to be used to generate income through marketing fuel wood and charcoal.

Acacia for building materials

In Tigray, almost all rural areas are building their houses using stone and wood. The most difficult task to build a house is to find wood and it is difficult to construct a house without wood. Iron can replace wood, but it is expensive and unaffordable.

Currently, acacia is widely used for construction materials in the area, as it is straight, tall and strong. It is very important to promote these characteristics, as the tree is suitable for construction and building purposes.

Acacia for farm tools

Acacia has also been shown to be very useful for the manufacturing of farm tools.

A 35-year-old farmer who is a member in a farmer group was asked whether he has used acacia as farm tool for himself or if he knew someone who used the same. He laughed and shared that he has a farm tool that he got from his brother and has used it for nine years and it is still being used. He emphasised its strength and as a result of this tool, has planted acacia in

his backyard and is expecting them to mature next year. He is planning to use some of the wood for himself and will sell the remaining in the market to support himself and his families.

Based on the above experience, people can be engaged in producing acacia trees for farm tools. It is also very important to integrate with other activities such as using the leaf for animal feed, the seed for human food, and the tree as a whole for soil and water conservation measures. One of the traditional farm tools used by the local people is shown here.

Acacia for soil and water conservation

Tigray has started and is currently undertaking a massive environmental rehabilitation program in the whole region. To strengthen the ongoing program it is very important to identify and plant adaptable, drought-tolerant and fast-growing multipurpose tree species that contribute to environmental rehabilitation. Among these species is acacia for it is widely adapted to the marginal and dry lands of Tigray (project design document 2009).

One of areas visited during the research was Abraha WeAtsebeha. Discussions with farmers revealed those three years prior, the area was almost barren of trees and it is now currently "full of trees and grasses". Acacia is among the trees planted in the region. It is suggested that the area has fully recovered and become a safe haven for many birds and wild animals. These respondents shared that it is wonderful to see such kinds of changes within a short period and is an indication that it is possible to reclaim the degraded areas in the region using acacia, which is fast growing and drought resistant.

Acacia trees can grow in extremely eroded land, backyards, farmland and closure areas. Though it needs some groundwork to internalise the use and importance of the tree to the community, landless youth, women and other community members can be organised into groups as acacia seedling producers so that they can sell acacia seedlings to the community, NGOs and government. The group could employ themselves in producing acacia seedlings to different closure areas, farmlands and to other similar areas. Closure areas could also be provided to the landless and youth to generate income using acacia trees as fuel wood, farm tools, bee forage and animal feed. In order to protect the land from erosion the owners of the closure area could sell their acacia produce through a carry-and-cut system. They also need to protect the trees that provide them seeds.

At left is a three-year-old acacia tree on recovered land.

Acacia as a source of income

Acacia can be one of the major sources of income if users are organised, strengthened and the tree are easily available in the area. The formation of credit and saving groups among acacia users is of a paramount importance for accessing credit and facilitating market linkage among the different groups.

The groups could start by producing acacia seedlings in their nursery sites that will be provided by the local Administration called Peasant association (Kebeles). They will buy acacia seeds from acacia tree owners and others who can collect the seed from closure areas, based on the market price. After maturity the groups would also sell their acacia seedlings to the different users. The process will go on generating income through the chain.

In considering income generation, it is important to consider the integration of acacia growing groups with other related income-generating activities such as beekeeping, fattening animals and dairy production. Those activities are directly linked and related to acacia production. Acacia trees will help people to "hit two birds with one stone". The groups are engaged in producing acacia for consumption, and at the same time they are also engaged in animal production.

Scaling-up acacia production in the region

Over-dependence on a few plant species exacerbates many acute difficulties faced by communities in the areas of food security, nutrition, health, ecosystem sustainability and cultural identity (Underutilized plant species, 2006).

The world is currently over-dependent on a few plant species. It is also true for Tigray. The feeding habit is mostly dependent on agricultural products, specifically on wheat, maize, teff, barley and beans. Tigrayans rarely use wild plants due to their availability and entrenched feeding habits. Due to such kinds of feeding habits, people are susceptible to food deficit and acute malnutrition almost every year.

Diversification of production and consumption habits to include a broader range of plant species can contribute significantly to improved health and nutrition, livelihood, household food security, and ecological sustainability.

Scaling up plants that are not commonly used by the community, such as acacia, is very important to combat hidden hunger and offering income generation options. Though our capacity to conserve and improve the yield and quality of acacia seed is limited, it is very important to use the most effective means of commercialisation, marketing and policy frameworks to enable us to promote its use and maximise its economic value in the region. Policy and frameworks need to be designed by the partners during the project design to include Acacia seed for human consumption. Scaling up acacia production in the region should intentionally include and the active participation of all concerned government offices at all levels, donor agencies, non-governmental organisations that have presence in the area, private sectors and the community at large.

Peter Yates, in his research entitled "Australian Acacia" 2010, stated "Successful implementation will be dependent on an effective campaign that can provide the best genetic material, deliver the necessary resources at the village level, and provide effective and ongoing training in acacia cultivation and its preparation as food".

It is also very important to note that market development through practical interventions, entrepreneurial training and fostering of public–private partnership is necessary at all stages of the value chain to improve the supply and demand of the product under discussion. Market development includes the development of functioning market chains, provision of relevant training for the partners, and support for business development services.

In considering scaling up of acacia production for its multipurpose use, it is important to consider the following points that will speed up the scaling-up process in the area.

Intentional involvement of partners in the process

Government offices that are responsible for policy making and influential community members should be intentionally involved in the scaling-up of acacia production. Before involving them it is essential to identify the roles and responsibilities of the offices so that they can contribute what is expected from them.

The major government offices that should be involved in the process are health, agriculture, administration, water and sanitation, cooperative promotion, small and micro enterprise agencies, marketing promotion, TARI, and natural resource management.

It is also important to include micro-financial institutions, farmers' associations, nongovernmental organisations operating in the area, private sectors also operating in the region, saving and credit groups, honey producer cooperatives, nursery site operators, farmers, research groups, farmers' extension groups, womens and youth associations.

It is also equally important to incorporate awareness creation and internalisation of the scaling-up concept. It is only then that the partners can actively and intentionally participate in the process. Internalisation and awareness creation will be one of the major activities that will be incorporated in the WV Ethiopia project re-design.

Partners listed to participate in the process will play a significant role in materialising the scaling-up process based on their identified roles and responsibilities. The government health office at all levels will engage in assuring the implementation and education of the nutritional value of acacia seed for human food. The implication of the seed for human consumption should be assessed and released based on a study made by the health department. Thus, the role and responsibility of the health department will be to identify and list the nutritional value of the seed for children, mothers and other members of the community. TARI will also work with the health department in the research process

It is also true for the agriculture department at all levels. The department will be responsible to assure that acacia plant is useful for animal feed, farm tools, building materials and soil and water conservation measures. The department would also play an important role in planting the tree in degraded areas. The department in collaboration with the administration would also identify the target beneficiaries and target areas the plant will be planted. In addition to this the responsibility of the department would be to draft bylaws on how to use closure areas and check its applicability in the community.

The cooperative promotion office would also be responsible to organise and strengthen groups engaged in acacia seed production for different uses. The groups that are expected to be organised are seedling producers, acacia seed marketing groups, acacia growers' groups in closure areas that will be engaged in the sale of acacia for fuel, farm tools, building materials and seed for both nursery sites and seed marketing groups that will be used for human food.

Micro financial institutions should also provide credit for the different groups to run their businesses successfully. This agricultural marketing promotion office should also facilitate and assist the groups in marketing development aspects including capacity building such as provision of business development services, entrepreneurial skill, and conduct value chain development.

Organise and strengthen acacia seedling procedures

In the scaling-up process, it is essential to identify the major activities to be scaled up. One of the essential activities that should be given due emphasise in the process is to organise and strength acacia seedling producers. The producers should be organized into groups and be capacitated. The groups will also form savings and credit associations. The main purpose of those groups is to produce acacia seedlings for sale. Respective peasant associations would provide land for the nursery sites and the respective agriculture office will also support them technically on how to prepare and produce seedlings. In addition to this the agriculture department would assist them in linking the groups in to different closure areas and degraded land that will be needed to plant the seedlings raised by the group.

Organise and strengthen acacia seed marketing groups

It is almost similar with that of the seedling group; the difference is that those groups are more involved in direct consumption. The groups can collect the seeds from different sources such as:

1. they can grow at their farmland or backyard;
2. they can buy/collect from closure areas;
3. they can buy/collect from different sources such as market, nursery sites, etc.;
4. they can buy/collect from government owned forest areas;

The seed marketing groups can also form saving and credit associations among themselves. In most cases, credit and saving associations are important for the members in the following ways:

- introduce a saving culture;
- serve as social security fund;
- borrow when they need and pay when they can.

They can also access micro-financial institutions if they need credit. The cooperative promotion office and agriculture department will also provide technical support with respect to their mandate. The intervention of NGOs is important to support them in areas where they are not in a position to stand on their own feet. Those groups will be trained in business development service and entrepreneurial skills so that they can sustainably and successfully run their business.

Chris Rowlands has clearly stated in his research on an analysis of the cereal market in Niger, the importance of organising farmers in a group: "It is necessary for farmers to organize themselves in order to refine their marketing skills and ability to seek out processors and traders who are willing to pay…" (Niger Cereal Analysis, 2008)

Organise and strengthen acacia growers in closure areas

This is the third group in the chain that needs to be organised as groups so that they can easily find services. The region is currently providing the landless and youth with closure areas so that they can use it for planting different trees to integrate with income-generating activities. The experience is that those groups will use the closure areas for bee production, dairy and fattening. The system will be zero grazing and they will use the cut-and-carry system

The steps and process of organising is almost the same as above. Here the groups will undertake different activities, including:

- beekeeping production
  - production of honey
  - bee colony production
  - wax
- fuel wood
- farm tool
- animal feed based on cut and carry system to feed their
  - dairy production
  - fattening
- acacia seed for seedling production
- building materials
- producing Acacia seed for
  human food in the form of
  - enjera/chapatti/local bread called kita
  - soup/locally known as suko

Acacia seed for human food has not yet begun in the region. In order to address this, it is necessary to undertake two activities side-by-side. One is to aggressively promote the seed as food through a range of methods such as incorporating the topic at all school clubs in the acacia growing areas, discussions with respective government offices, forums, group discussions among all market actors and users. The second one is to scale up processes to increase the production of acacia in the area. Department of agriculture and TARI in collaboration with NGOs and the community at large can actively participate in the process.

Capacity building and internalisation

This is the most important element in the scaling-up process. Partners who are expected to engage fully in the project should and must understand the purpose of the scaling-up process. They have to clearly understand the purpose of the acacia tree and its uses for the community. They need to support and actively participate to fulfil the mission of the project.

Internalisation begins in convincing the partners, especially government officials, who are responsible in policy and decision-making. It is also important to include the community and religious leaders, and to consider major development concerns such as gender, children and neglected groups of the society. Last but not the least, we need to build capacity and create awareness among the community who are our end-users. Capacity building here can include training, workshops, discussion groups and publications. This can be food preparation lessons for community members in the area and undertaking food preparation trials within the community. It can also include emergency food distribution for the needy and promoting acacia seed for human food through radio, television and newspapers. Introducing the concept in school clubs and teachers associations is also vital so that it can be incorporated into classes. Finally, it is important to incorporate it in health extension services to provide orientation in its nutritional value to mothers and children.

Organise and strengthen credit and savings groups

One of the best means to begin the scaling up of the acacia seed for human food is to organise the users at different levels in saving and credit groups. It is very important to organize the users into associations so that they can have financial capacity and saying power in their day-to-day activities.

The savings and credit groups will assume the following groups, which of course will be organised independently, yet the process and management will be the same. The groups are:

Acacia seedling producers' credit and savings groups: Those groups would be mainly engaged in producing acacia seedlings for sale as income generation activities. They buy seedlings from different groups such as farmers who own acacia trees on their farm and/or in their backyards, people engaged in closure areas who sell seedlings.

Closure area credit and savings groups: They are engaged in different income generating activities within the closure areas. They buy seedlings from nursery sites and plant them in the closure areas. The closure areas are their source of livelihood. As acacia is a fast growing tree, they can use the tree for animal feed, farm tools and human food. These groups are the main source of acacia seed for the seedling producers and acacia seed market for human food.

Acacia seed marketing credit and savings groups: This group deals with the human food component. They are organised to market the seed to the people who will consume the seed as food. They can also be involved in promoting the importance of Acacia seed as human food and its nutritious value as well as its multipurpose use for both human and animal food and feed respectively.

Integrate the program with World Vision Ethiopia Area Development Programs' interventions

"A further factor giving great promise in Tigray is the dynamic engagement of World Vision Ethiopia and the Tigray Agricultural Research Institute in exploring the potential of Australian Acacia' (*Australian Acacia* 2010)

The current project should be integrated with the existing projects in the World Vision Ethiopia operational areas. Integration can be done in many activities but just to mention a few of them:

The acacia project mainly focuses on planting acacia seeds for different uses yet at the same time World Vision Ethiopia ADPs are also involved in food security and soil and water conservation measures. Similar activities undertaken by both programs at the same place should be integrated and implemented jointly. Such activities could be managing closure areas, dairy production, beekeeping and food security programs.

World Vision Ethiopia ADPs also provide beekeeping, dairy and seedlings for people who live in degraded areas. Both projects can jointly support similar activities for the target households. World Vision Ethiopia ADPs can provide bees for target households in the areas where the acacia project is running as a closure area. The same is also true for dairy production.

The above picture shows a place where a group of farmers have been organised by World Vision into a beekeepers association. The acacia project could be integrated with this intervention to boost the production of honey. The area is empty of trees that offer the bees feed and shelter.

Promote the multipurpose use of production

The tree is found abundantly in the region but what is needed is to promote the seed for human food, as Peter Yates said in his research. The time consuming task of scaling up acacia seed production is then removed, and the focus can be brought immediately to education (*Australian Acacia*, 2010).

To promote acacia consumption as a human food and its other uses it is necessary to use a range of different means. Promotion can be through the media, but it is also important to use workshops, seminars and discussion groups among the different stakeholders.

Opportunities

World Vision experience for such innovation

World Vision Ethiopia and World Vision Australia have excellent experience in bringing innovation to the communities they serve. The acacia project is one of the projects considered as innovation in the area. With innovative approaches we have implemented successful projects. Examples include creating market linkage for mango, coffee and apple producers.

The region is one of the food deficit regions in Ethiopia

There is a good opportunity to implement acacia production in such food deficit areas. Most food deficit months are March to July, whilst acacia is harvested in the months of January to March. Acacia can also be stored for a long period.

Government policy towards environmental protection

The government of Ethiopia is dedicated to environmental protection. The regional government has passed a law that states every person who is living in the countryside should contribute 40 free working-person days per year to environmental protection activities. Almost in every part of the region check dams, terrace and soil bands have been created to tackle the current land degradation. We can use this opportunity to promote acacia plant to protect against land degradation and at the same time to use the plant for both animal and human consumption thereby supporting the government's mission and improving the livelihood and security of the community.

Community willingness and experience

The community have already recognised that the plant is strong, tall, fast growing and straight for farm tools and building materials. They have also tested that the leaf of the plant is suitable for their animals as forage; especially how the plant is excellent for fattening and milk production. They also know how to mix the acacia leaf with a local beer by-product for animal feed. The experience and willingness of the community is there and we need to exploit this wonderful opportunity to introduce and expand the use of already existing acacia plant.

Remarkable changes observed in the area

The regional government is trying to tackle the century-old land degradation in collaboration with various partners. This collective effort has brought a significant change in environmental protection. It is common to see people here and there caring for seedlings, to plant on their farmland and in their backyards, to protect their land from the usual land degradation. The change can be observed in both the attitude of the people towards environmental protection and in the land now covered by plants and protected from degradation. It is important to appreciate and exploit the existing potential now in the community and develop it to the benefit of the whole community through introducing and expanding the acacia plant.

Challenges

Community attitudes

One of the challenges that the acacia project will face is the community attitude to the use of the plant as human food. Acacia as human food has not yet been introduced in the area. To change the habits of the community that have existed for a century might be difficult in a short time, especially for the old and the religious leaders. We need to be careful promoting and introducing the acacia seed for food to the community. Government officials and policy makers should play a significant role in convincing the community by using forums and discussions within the community.

Wild animals and birds

The second major challenge the project will face is from wild animals and birds. The most common wild animals that feed on acacia leaves and seeds are monkeys. There are many monkeys in the areas where acacia grows. Monkeys are considered as challenges for the project because not only do they feed on the leaves and seeds but they also they break the branches in order to access the leaves and seeds more easily. One of the best solutions for this is to organise landless farmers, youth, and women groups and provide them with access to the closure areas so that they can generate income from activities using the acacia project as an entry point. They can implement activities like:

- beekeeping
- fattening animals and dairy production,
- use of acacia trees for purposes like, fuel wood, farm tools and building materials
- acacia for human food

Nutritional value

To clearly test and classify the nutritional value of the plant may take an unexpected period of time. This is associated with the intentional involvement of the government offices especially the health department at all levels, and the respective decision-making government bodies. It will not be easy to convince the aforementioned government offices to actively and intentionally be involved in the process. The health department is not currently involved in the project; it may take some time to bring the office on board.

Recommendations

The following points are recommendations for the success of the scaling-up of acacia production.

1. Intentional involvement of the respective government offices and the community in the design, implementation, monitoring and evaluation of the project.
2. Re-design of the existing acacia project to include the multipurpose use of the plant.
3. Immediate commencement of testing the acacia nutritional value in collaboration with the health department.
4. Aggressively promote that acacia is useful for human food in addition to its other uses.
    a. Intentionally involve concerned government offices in the process.
    b. Use public and government institutions to promote the issue periodically and whenever necessary.
    c. Use public and government media to promote acacia as human food.
    d. Involve the community in the process from the beginning.
    e. Conduct research with institutions to identify the nutritional value of acacia and the best type of plant
5. Demonstrate in different forums the multipurpose use of acacia plants in different parts of the world.
6. Integrate the project with similar WV interventions.
7. Include micro enterprises in the program.
8. Organise and strengthen marketing groups in order to promote acacia seed marketing facilities.
9. Conduct intensive study on the type and use of the acacia trees in Tigray.

References

Atsbi ADP re-design document 1997.

Rinaudo, R. (2010), *Trip Report and recommendations, re-greening Tigray*, World Vision Australia.

Rowlands, C. (2008). *Niger Cereal Market Analysis*, World Vision Australia.

Yates, P. (2010). *Australian Acacia*, A research Project in Partnership with World Vision Australia, Charles Darwin University, Australia.

Challenges in new food product development: A case study of lipid-based nutritional supplements / ready to use foods for management of acute malnutrition in resource poor settings and potential for utilization of acacia powder

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Background

Malnutrition is common in the developing world and associated with disease and mortality. Malnutrition frequently occurs among children in the community as well as those with acute illness. Despite global improvements, malnutrition still underlies half of the inpatient morbidity and mortality rates among children in resource-poor settings. Malnutrition limits development and the capacity to learn and grossly undermines future economic progress of both individuals and states. Food-based approaches have been an integral part of efforts to alleviate the impact of malnutrition.

In order to manage acute malnutrition, multi-faceted approaches that include provision of adequate healthcare, clean water, sanitation, a clean environment, in addition to appropriately formulated foods are needed. Currently, ready to use therapeutic foods that mimic WHO F100 are recommended for use in the treatment of severe acute malnutrition among children aged below 5 years [1].

New food product development: definition and steps

New food products may be classified line extensions, repositioned existing products, new forms of existing products, reformulation of existing products, new packaging of existing products, innovative products and creative products[2].

Figure 1: Classification of new products

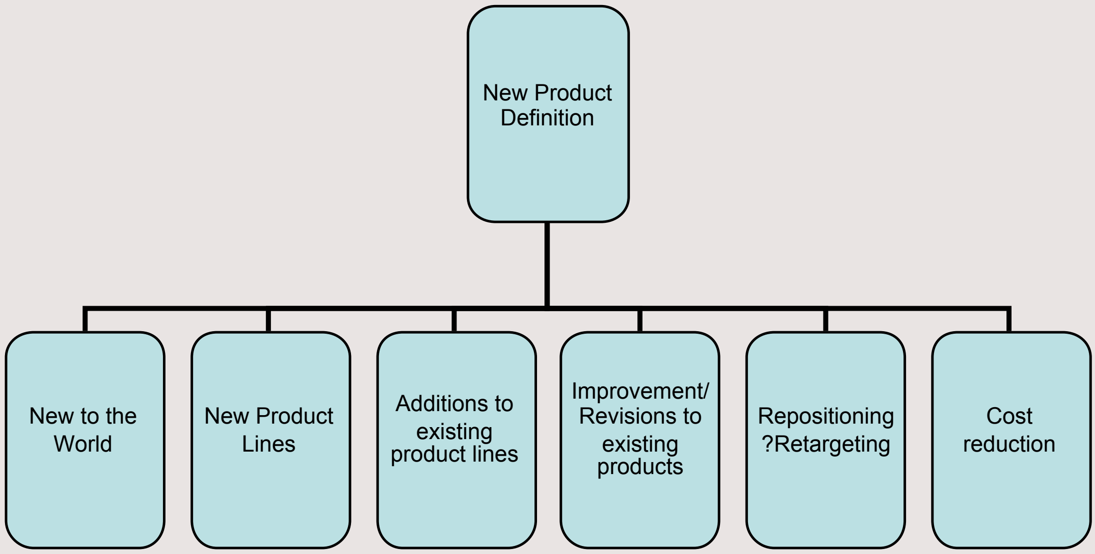
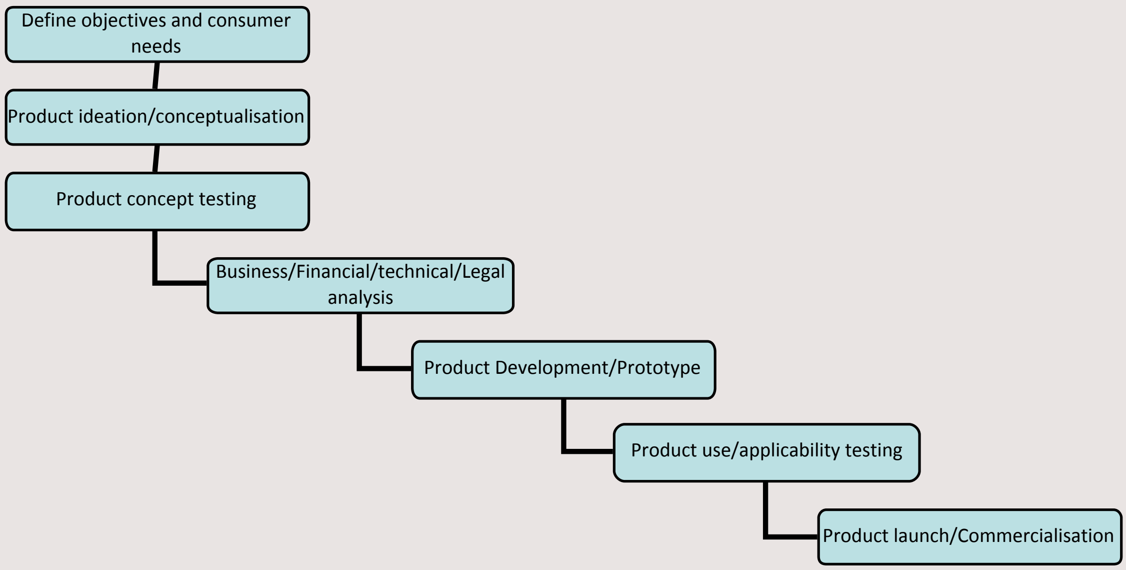


Figure 2. Key steps in new food product development.



Formulation, acceptability and effectiveness and proposed improvements of ready to use foods in managing acute malnutrition: Valid Nutrition experience

Valid Nutrition (VN) believes that any food product ought not be taken to the market without pre-requisite rigorous generation of evidence through acceptability and efficacy assessment based on sound randomised controlled trials. As such VN must undergo the following key product development steps, but with a lot of emphasis on palatability, tolerance and efficacy/effectiveness. VN also strives to place product development efforts in the public domain via peer-reviewed publications.

Upon publication of results, VN puts all data on the formulated foods including the recipe itself in the public domain in order to enable rapid scaling up of strategies that have been proven to work, by any interested party. All VN formulations will not be patented, as such, this expands the horizon for competition in order to widen the coverage of humanitarian efforts to address otherwise debilitating malnutrition.

Valid Nutrition has since 2008, with funding from Irish Aid, developed four new alternative soya-maize-sorghum (SMS) recipes including:

- milk-free ready-to-use soybean-maize-sorghum (SMS) therapeutic food for treatment of SAM (SMS-RUTF);
- soybean-maize-sorghum ready to use supplementary (SMS-RUSF) and,
- soybean-maize-sorghum ready-to-use complementary food (SMS-RUCF) with very little milk and;
- a milk-free soybean-maize-sorghum RUTF specifically designed for HIV-infected adults (SMS-RUTFH).

These new recipes all proved to be highly acceptable among target populations. Two post-acceptability effectiveness trials were completed in Zambia (SMS-RUTF) and DR Congo (SMS-RUCF). Two pending trials include 1) the effect of SMS-RUSF in treating moderately acutely malnourished children and 2) the effect of a specially designed SMS-RUTFH in treating severe acute malnutrition in HIV-infected adults receiving ART.

SMS-RUTF achieved mortality rates that are equivalent to those achieved using standard peanut/milk recipe RUTF (P-RUTF), although it is marginally less effective than P-RUTF in treating SAM among children in terms of rate of recovery. However, the use of SMS-RUTF saves US$900 per MT (this would be equivalent to a saving of US$10 per child treated assuming 10kg of RUTF over 8 weeks).

A follow up results dissemination meeting held on the 14th April 2011 in Lusaka at the request of the Zambian Ministry of Health, generated positive interest in the product among key players including the local Ministry of Health, UNICEF, WHO, USAID and Concern Worldwide.

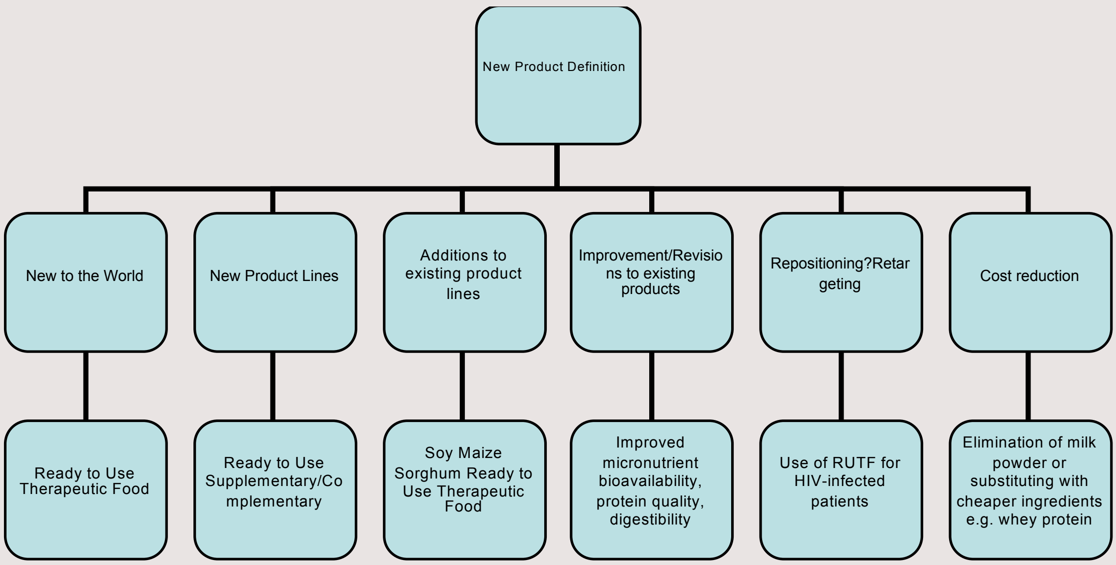
SMS-RUCF: Effectiveness trial results in DR Congo show that there is no difference between SMS-RUCF and fortified corn soy blend (CSB) in impact on weight nor height gain after 6 months of intervention (6-12 months of age). Although these results are disappointing, an analysis of a sub-sample of 60 children whose food intake was closely monitored showed that those in the SMS-RUCF group gained significantly more weight than those receiving CSB.

In order to improve the new group of soya-maize-sorghum ready-to-use foods (SMS-RUF) formulations, key technical issues must now be addressed including:

1) bioavailability of key minerals (in particular iron and zinc),
2) optimisation of long-chain essential fatty acid content;
3) improvement of protein content and quality of SMS-RUCF and SMS-RUSF;
4) improvement of texture with better milling required;
5) elimination of oil separation during storage.

Figure 4 places the formulation developed by Valid Nutrition in the context of new product classification.

Figure 4: Classification of VN ready-to-use foods



Incorporation of acacia powder in ready to use foods for management of acute malnutrition

Acacia seed as a source of human food has been a subject of increasing interest and research in recent years. Much of this work is based on an understanding of traditional Aboriginal use of many of these species[(3)]. The overall nutritional value of certain Australian dry-zone acacia seeds is typically high, reflecting their protein, fat and carbohydrate content, and the seeds contain no or low levels of toxic or anti-nutritional compounds[(3)]. Additionally acacia seed is rich in essential minerals[(4)], namely, calcium (141–243mg/100g), iron (4.8–10.4mg/100g) and zinc (2.2–5.9mg/100g). Acacia seed is an important source of essential fatty acid[(5)], namely linoleic acid (as ù -6 fatty acid) and linolenic acid (as ù -3 fatty acid). Phytate and trypsin inhibitor contents were low; oxalate was fairly high (2.2–2.6g/100 g), but tannin was on the high side 66.0–86.7mg/g) compared with legumes[(4)].

Currently acacia seeds have wide applications in the food industry namely: flavouring in confectionery, sauces and ice cream; coffee substitute; edible oils; flour for biscuits, breads and pasta; roasted and ground flours; and chocolates.

There has been a lot of interest in the nutritional benefits of acacia seed to human populations, but more needs to be done in this area in light of ever increasing global food insecurity and escalating levels of malnutrition.

Acacia seed flour was used for dietary trials with laboratory rats at Obafemi Awolowo

University in Nigeria. Nutritional and safety trials showed that 20 per cent *A. colei* seed flour in millet-based diets improved growth rates and that rats remained in good health for trials lasting several months[4]. Some adverse health effects (hair loss, eye infections and occasional morbidity) were observed in some experiments when acacia seed flour comprised 40 per cent or more of the diet, but supplementation of diets with the amino acid methionine improved the animals' health and boosted their growth. Three generations of rats were raised on sorghum-based diets incorporating 20 per cent and 40 per cent acacia without any mortality or evidence of birth defects. Animals on 40 per cent acacia failed to reproduce when fed diets containing 12.6 per cent crude protein, but reproduced successfully when the crude protein level was increased to 18 per cent[4].

In human studies, incorporating acacia seed flour could extend food supplies by up to 25 per cent without decreasing the quality of the local diet. However, caution must be observed and follow-up studies are required to check the effects of longer-term consumption of acacia flour at 25 per cent of the diet in order to confirm that this new food is safe for children, pregnant women and other special groups [4].

Cross cutting challenges in development of ready to use foods

RUTF is very effective for children with severe acute malnutrition in both hospital and community settings. A study from Malawi[6] where children with oedema were exclusively treated with RUTF for eight weeks report a high recovery rate (83%). A controlled, comparative, clinical effectiveness trial conducted in southern Malawi[7] concluded that children on home therapy with RUTF recovered better (79% vs 46%) and were less likely to relapse or die (8.7% vs 16.7%) than children on standard therapy based on international guidelines. An operational study[8] in southern Malawi found that home-based therapy with RUTF resulted in acceptable recovery in both severely malnourished (89%) and moderately malnourished (85%) with no requirement for formally trained medical personnel. A meta review[9] of community-based therapeutic care (CTC) with RUTF programmes concluded that such approaches are associated with lower case-fatalities, and increased recovery rates both of which may be attributed to increased access to services, reduced opportunity costs, early presentation and compliance, and increased coverage.

The most widely used RUTF spread is a mixture of milk powder, sugar, vegetable oil, peanut butter, vitamins, and minerals[10] RUTF is available as a commercial product packed in oxygen-free foil sachets. Recently, there has been local production of peanut-based RUTF in several developing countries by private companies including Valid Nutrition, an Irish-based charity with RUTF production facility in Lilongwe, Malawi. In Kenya, Insta Products EPZ Limited based in Athi River is currently producing RUTF under license from Valid Nutrition.

Despite the positive developments in RUTF production and evidence that it works in treatment of SAM, there are issues that need addressing. Firstly, local production of RUTF in any particular setting is mainly limited by ingredient availability hence recent recommendations for ingredient diversification. Further, the intensive use of milk in the formulation of RUTF (25–35% w/w) makes them too expensive for sustainable use in resource-poor settings. There is a lack of evidence on whether non-peanut-based RUTF with none or, minimal amounts of milk powder may have similar nutritional benefits. Initial research into the use of an RUTF formulation based on chickpea, sesame and maize with a low milk content has proved effective in addressing acute malnutrition in HIV positive adults[11].

Secondly, the use of RUTF to other populations including HIV-infected adults and moderately malnourished children [12] has gained momentum. A randomised, investigator-blinded effectiveness trial in Malawi among non-pregnant adults starting ART with BMI <18.5kg/m^2 (average 16.57 kg/m^2) found greater BMI, greater weight and fat free mass gain with RUTF than with corn soya blend after 3.5 months of intervention[13]. Recent work from Malawi[14] reported good recovery among malnourished, HIV-infected children not receiving antiretroviral chemotherapy. Home-based therapy RUTF was associated with more rapid weight gain and a higher likelihood of reaching 100% weight-for-height compared to corn-soya blend.

The use of RUTF as a supplementary food among children at risk of malnutrition has also been reported[15]. In this study children were given either RUTF or micronutrient-fortified corn-soya blend for up to 8 weeks. Children receiving RUTF had greater recovery (58% vs 22%), and greater rates of weight gain (3.1 g/kg/d vs 1.4 g/kg/d) than children receiving the corn-soya blend.

However, the use of RUTF among children with MAM may not be safe given the high concentration of nutrients in the formulation. More recently it has been shown that fortified spreads with milder nutrient concentration compared to RUTF are more effective in treating MAM compared to CSB [16]. Additionally, there are new recommendations for the level of micronutrients for use in fortifying supplementary foods.

Recent evidence shows that lipid-based ready-to-use foods other than RUTF may be used in the prevention/ treatment of moderate malnutrition with a positive effect on growth among infants. A Ghanaian study[17] compared the growth of infants given complementary foods fortified with either micronutrient sprinkles or crushable micronutrient tablets on one hand, or fat-based peanut butter paste on the other. Infants given the fat-based peanut butter paste had greater weight-for-age and length-for-age at 12 months compared to those in the other two groups. A recent study[18] from Malawi compared the effect of using peanut-soy based fortified spread and corn porridge fortified with fish powder as complementary foods on growth in rural Malawian children. Children who received peanut-soy spread gained 110 g more from 6–12 months of age than children receiving the fish-fortified maize porridge.

The continued use of RUTF in treatment of SAM among children under 5 years of age is strongly recommended as there is solid evidence that it works. More work remains to find appropriate ready-to-use foods for HIV-infected adults, and moderately malnourished children. Additionally, cheaper RUTF based on diversified ingredients and local production are needed to enhance affordability and access. A lot of research work is currently underway to test the efficacy of non-peanut RUTF in the treatment of SAM among children. Additionally, there is a large amount of research on the efficacy of ready-to-use supplementary (RUSF) and complementary (RUCF) foods for prevention and treatment of moderate acute malnutrition.

Compared to powdered food blends such as CSB/WSB, ready to use foods offer several advantages. Typical ready to use foods will be solid, energy-dense lipid pastes that resist bacterial contamination because of low water content. The fact that RUFs can be consumed without cooking may enhance hygiene, and minimise opportunity costs for caregivers.

There is great potential in the use of ready to use foods including RUTF, RUSF, and RUCF in management of acute malnutrition in resource poor settings in the most hygienic, cost-effective and sustainable ways. In the meantime, new RUF formulations must be tested for acceptability and efficacy among target groups. The different categories of RUFs need to be appropriately used within specific populations to avoid potential safety issues.

However, the following key potential barriers to successful development of RUFs need to be considered by businesses planning to enter into this interesting field.

1. Financial
   - Capital start up costs
   - High cost of borrowing
2. Imported raw materials
   - Vitamin and minerals premix, milk powder
   - Exposed to forex shortages
   - Currency fluctuation risks – depreciating local currencies
3. Quality issues
   - High aflatoxin incidence in peanuts
   - RUTF manufacturers forced to import peanut paste e.g. Kenya
4. Seasonality in demand.
   - Hunger season – in between harvests
   - Spikes in orders stresses the system
5. Limited number of customers
   - Approximately 80% of world volumes purchased by 3 customers; UNICEF, MSF and Clinton Foundation
6. Sustainability
7. Certification/validation/regulatory issues and processes
8. Regional barriers to food acceptance and inability to generalise results of effectiveness trials worldwide.

Conclusion

Malnutrition remains a huge problem globally, especially in resource-poor settings. To combat malnutrition, there is a need to put in place multi-pronged approaches that incorporate the use of highly nutritious foods. Ready-to-use foods are highly energy dense and convenient to use and there is growing interest in this market. There is a potential to diversify food ingredient use for RUF formulations. Ingredient choice may be tailored according to regional availability, acceptability, suitability to weather conditions and cost. Pressing issues such as dependency on imported ingredients, poor quality ingredients and sustainability need to be addressed.

References

1. Joint UN Statement on Community-based Management of Severe Acute Malnutrition http://www.who.int/nutrition/topics/statement_commbased_malnutrition/en/index.html
2. Wood, T. and Demilaray, A. An Examination of New Food Product Development Processes:A Comparative Case Study of Two Hazelnut Candy Manufacturers. *Agricultural Economics Staff Paper* # 384. June 1998. University of Kentucky.
3. Harwood, C., Rinaudo T., Adewusi, S.. *Developing Australian acacia seeds as a human food for the Sahel. FAO*: http://www.fao.org/docrep/x0963e/x0963e0c.htm
4. Falade, M.S., Owoyomi, O., Harwood C.E., and Adewusi S.R.A. Chemical Composition and Starch Hydrolysis of *Acacia colei* and *Acacia tumida* Seeds. *Cereal Chem*. 2005; 82(5):479-484
5. Tlili, N., Sakouhi, F., Elfalleh, W., Triki, S., Khaldi, A. Fatty acids, total phenolsm and protein of caper, acacia, cactus and carob seeds. *Asiatic J Biotech Res*. 2011; 2(04): 384-390.
6. Ciliberto, M.A., Manary, M.J., Ndekha, M.J., Briend, A. and Ashorn, P. Home-based therapy for oedematous malnutrition with ready-to-use therapeutic food. *Acta Paediatr* 2006; 95 (8):1012-5.
7. Ciliberto, M.A., Sandige, H., Ndekha, M.J., Ashorn, P., Briend, A., Ciliberto, H.M. and Manary, M.J. Comparison of home-based therapy with ready-to-use therapeutic food with standard therapy in the treatment of malnourished Malawian children: a controlled, clinical effectiveness trial. *Am J Clin Nutr*. 2005; 81 (4):864

8. Linneman, Z., Matilsky, D., Ndekha, M., Maleta, K., Manary, M.J. A large-scale operational study of home-based therapy with ready-to-use therapeutic food in childhood malnutrition in Malawi. *Matern Child Nutr*. 2007; 3 (3):206–15.
9. Collins, S., Dent, N., Binns, P., Bahwere, P., Sadler, K., Hallam, A. Management of severe acute malnutrition in children. *Lancet*. 2006; 368 (9551):1992–2000.
10. Manary, M.J. Local production and provision of ready-to-use therapeutic food (RUTF) spread for the treatment of severe childhood malnutrition. *Food Nutr Bull.* 2006; 27 (3 Suppl): S83–9
11. Bahwere, P., Sadler, K. and Collins, S. Acceptability and effectiveness of chickpea sesame ready- to-use-therapeutic food in malnourished HIv-positive adults. *Patient Preference and Adherence* 2009; 3: 1–9.
12. Castleman, T. Impact of specialized food products on HIV-infected adults and malnourished children: emerging evidence from randomized trials. In: *Proceedings of the International Food Aid Conference.* April 14-16, 2008 at the Westin Crown Center Hotel in Kansas City, Missouri. www.fsa.usda.gov/ifac
13. Ndekha, M.J., Manary, M.J., Ashorn, P. and Briend, A. Home-based therapy with ready-to-use therapeutic food is of benefit to malnourished, HIV-infected Malawian children. *Acta Paediatr.* 2005; 94 (2):222–225.
14. Patel, P.M., Sandige, H.L., Ndekha, M.J., Briend, A. and Ashorn, P. Supplemental feeding with ready-to-use therapeutic food in Malawian children at risk of malnutrition. *J Health Popul Nutr.* 2005; 23 (4):351–7.
15. Matilsky, D.K., Maleta K., Castleman, T. and Manary, M.J. Supplementary feeding with fortified spreads results in higher recovery rates than with corn/soy blend in moderately wasted children. *J Nutr* 2009; 139 (4): 773–778.
16. Adu-Afarwuah, S., Lartey, A., Brown, K.H., Zlotkin, S., Briend, A. and Dewek, K. Randomizes comparison of 3 types of micronutrient supplements for home fortification of complementary foods in Ghana. *Am J Clin Nutr.* 2000; 86 (2): 412–20
17. Lin, C.A., Manary, M.J., Maleta, K., Briend, A., and Ashorn, P. An energy-dense complementary food is associated with a modest increase in weight gain when compared with a fortified porridge in Malawian children aged 6-18 months *J Nutr.* 2008; 138: 593–598.
18. Phuka, J.C., Maleta, K., Thakwalakwa, C., Cheung, Y.B., Briend, A., Manary, M.J. and Ashorn, P. Postintervention growth of Malawian children who received 12-mo dietary complementation with a lipid-based nutrient supplement or maize-soy flour. *Am J Clin Nutr* 2009; 89: 382–390

The psychology of perceptions

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Rosemary Sayer is an experienced international communications specialist who has held senior positions in Australia and Asia. She now runs her own business in Western Australia. Her previous positions include: Public Relations Manager, Wesfarmers Limited; Corporate Affairs Director, Lion Nathan Brewery and Head of Corporate Affairs, Hong Kong and NE Asia, Standard Chartered Bank. Rosemary's diverse clients have included: Rio Tinto, NIKE, Jardine Matheson, Cathay Pacific Airlines, Austrade, Cisco, Save the Children Fund and the Association for the Blind. Rosemary has written two books is a director of WritingWA, a popular speaker, business facilitator, media and presentation trainer.

This is an edited transcript of Rosemary's presentation to the workshop.

Yes, I have spent a lot of time with scientists, academics, engineers. I have spent a lot of time with people who are passionate about what they do, which you can't help feeling in this room. You are all passionate about what you do and from my experience of working in communications, publications and marketing over the last 25 years, one of the challenges of being passionate about what you do and being involved intimately in what you do, is that sometimes you are so closely involved that you can't talk to anybody else other than those you work with. Given I am the session following closely after lunch, I am the light relief where you get to think about something other than the line of work you're in.

I am going to talk a little bit about market and perception and what actually happens when you communicate to people. I have spent some time here speaking to some of you that work in aid agencies and come from other countries and have been working with acacias for a long time. It's fascinating to me that if I hadn't spent a month reading about everything you've done I would be totally confused after this mornings session because there were a lot of different messages and none of you speak from the same hymn book – that's probably because you are all working in different countries, different organisations and different areas.

The challenge for our marketing group when we get together tomorrow is to try and distil some of what we heard and to try and develop a marketing and communications plan. My colleague Rob Francis will talk more about how we put the messaging together.

One of the challenges on a project like this is that you've got the project – acacias – you've got cultural issues and you've got to develop communications. I will look at it from the point of view that we're here in Australia and we need to communicate all the fantastic work you've done on the ground in African countries, in Chile and other places, and here in Australia, and how we might pull that together into a story … and the challenges we might face. I will

talk to you about some things you probably don't think about that you face in your everyday work. Globalisation has fundamentally changed the way we manage and think about communications; it's changed the way you do your jobs as you know. I rather like this quote from management guru Peter Drucker – and I think probably 20 years ago you had this feeling, you have this feeling today, but lets not let it happen again.

> "Grand visions and agendas create energy and excitement,
> but they can also cause confusion, fragmentation and inertia
> – even when we think we are driving towards the same goal."

Energy and excitement don't create clear communication. I know what Tony wants to get out of this time together: it's that we can all go forward together and keep the fires burning on this acacia project. I know what Rob and I and the communications and marketing people can do to start to help. What I have seen from everybody's papers and the work I have been immersing myself in this last month is that you have a great story to tell.

I want to talk about perception. I use this quote all the time: "Perception is reality".

> Our perceptions of a product, a company, a person, or even a country
> are driven by our first feelings, particularly through our sight.
> Perception may not always reflect the truth …
> but perception is reality

If I said acacia seeds to people in Australia some would scratch their head and say "Is that the wattle?" And if I said acacia seeds and Africa they would go "Where is Africa"? They wouldn't know and you would have to explain that Africa is a continent not a country. So we have perception problems when we're talking about "acacia" and "Africa" and about what we're doing. We have to talk about perceptions of the acacia and we have to talk about perceptions of what we are trying to do with our product.

That's a problem we face with anything we are trying to market, be it a product or ourselves. I wanted to talk about how you market yourselves. Each of you market yourselves every time you stand up to speak. I graded you all on your presentations this morning (and you can come and see me privately if you want to know your score). [laughter] One of the things you're not allowed to do is speak to the PowerPoint presentation. All of you did that. Don't do it. Even if you're a scientist you're not allowed to do that! [laughter] You've got the screen in front of you – talk to that – that way you're always facing your audience.

Pens and papers out, this is a quick 2-minute exercise about your perception of these products. I am going to flash up a number of very quick photos of a product, place or a person. Scientists and academics will write down what they see. I don't want you to do that – I want you to write down the first one or two words that come to mind when you see the picture and what you feel immediately.







What did you see? What was your perception? I am going fast because a perception is what you see. Back to the swoosh, Tony what did you see? "A running shoe." Perceive? What did you see (someone else)? You saw child labour. Exploitation, anybody see any thing different? … Quality, marketing. Did you all see it was Nike?

You all saw Apple Computers, what perception did you have? Technology … innovation … quality and innovation, not Microsoft.

(The discussion continued for a couple of minutes. Then …)

The Acacia Project needs to speak to "Hearts and Minds" …

Brands provide aspiration. They provide a promise. Brands tell a story.

People want to be associated with success.

We have a great story. Years of research. Acacias are proven and now accepted. We aspire to help to lift people out of the cycle of hunger.

We want to do more – join us.

What we need to do is give an aspirational story if we are going out to donors or to get people interested and involved – and this is something you can do in your organisations. You need to provide a promise and a story. People want to be associated with a promise and success, but you need to turn around the way you write the story for the audience. It's not about you and your research – it's about them. I was talking to Ross (Britton) about a donor project he was involved in where he had to change it because the donor wanted to do something different. It wasn't that difficult but to get them involved and get the funding he needed to modify it a little to get success. It seems to me you've got a great story, acacias are proven and accepted in a lot of the work Tony and the team have been doing, it's an aspirational story where we want to lift people out of hunger. That would be the story I would tell in Australia – we want to do more, join us.

Our challenge is to find a positioning for the work you've been doing. Currently, it's not a consistent story with all the pieces of the jigsaw forming one piece. We don't have anything that we can tell the broader Australian community – we don't have consistent messaging. We need to media train our spokespeople, although I thought Mr Tony was great last night, and then we need to follow that with an agreed marketing and communications plan. There

is so much knowledge in this room, so many great individual stories, it would be fantastic to capture them all.

Strong clear positioning is the cornerstone for building a strong positive reputation that endures over time.

In our communications and marketing to the broader Australian community we must engage them and make them advocates.

Consistent, clear messaging,

media and presentation train of spokespeople who

follow the agreed marketing and communications plan (once we have one!).

I would like to conclude by talking about the 5 C's of branding:

1. Compelling proposition – haven't really got one yet.
2. Clear distinctive position – haven't really got one yet.
3. Consistent delivery of the promise. What's our promise – haven't really got one yet.
4. Connection with stakeholders – we're doing that on the ground, we've got very good people doing that on the ground. If we look at other stakeholders such as donor organisations and other research groups, we're still working on that.
5. Commitment to leadership and innovation – you're there in spades.

Wattle we do to get the message out?

Rob Francis
Community Projects Manager
World Vision Australia

Rob Francis is Community Projects Manager at World Vision Australia where he established the national forum series "One Just World" which has become one of the leading discussion forums on poverty and development worldwide. Prior to World Vision, Rob had a long career producing and directing top-rating TV programs, working on corporate communications campaigns (notably Landcare), as a published author, and managing a super-premium vineyard Victoria's northeast. Rob has a degree in Agricultural Commerce, Diploma of Education, Diploma of Film & TV Production, and he is currently completing a Master of Corporate Environmental and Sustainability Management.

This is an edited transcript of Rob's presentation to the workshop.

Firstly, I would like to thank AusAID for their support of this workshop as part of a broad partnership with non-government and community organisations around the theme of community engagement in Australia's aid program; which in turn will help create sustainable livelihoods for the poor in developing countries.

The aim of Rosemary Sayer's and my presentations is to discuss how we might take your research and knowledge – the scientific and development recommendations of this workshop – to the community and inspire it to become involved.

I'd like to talk about three things – three contentions:

1. Most people generally are ignorant about what aid and development does.
2. We need to tell a simple story in order to get the message across.
3. Communication is a two-way conversation.

And I'd like to start by showing a video called "UK Aid: View from the Street". It was produced by ONE, a grassroots advocacy and campaigning organisation, co-founded by rock star Bono. ONE works to raise public awareness about extreme poverty and preventable disease, particularly in Africa, by pressuring political leaders to support effective policies and programs that can improve peoples' lives.

The question this video poses is: what do ordinary people know about aid and development?

(Video shows the lack of knowledge about the UK Aid Program by ordinary people from various walks of life – hence "View from the Street". At first the participants are very sceptical about aid, but as the video progresses, they are awakened to the real facts and become supporters of the aid program.)

It can be downloaded at: http://www.youtube.com/watch?v=I8ybGVSCckc&feature=player_embedded

1. People generally are ignorant about what we're doing

The video illustrates what I'm contending in my first point – that ordinary people simply don't know about aid and development and unless we make them aware they will remain ignorant. I would also suggest that the more obscure the activity the less people will know about it. Just as ordinary people in the UK don't know about aid, I am sure that ordinary Australians don't know what you are doing with the seed of our famous emblem. But what I found so interesting about the people in the video was that, as they got information about aid and development, the facts and figures and the issues, they changed their position quite readily to support it.

It's interesting to see how Australians look at aid and recent research illustrates that 85% support aid, but it's moral support and as soon as you get into issues of substance, peoples' knowledge falls dramatically away.

Australians' attitude to aid?

- 85% of the Australian public overwhelmingly supports aid in principle, but they have a shallow understanding of aid and development issues
- People generally support aid for moral reasons. However, this support does not mobilise the public in the same way as domestic issues
- When greater information is provided on aid and aid expenditure, it generally results in increased community support
- Trends show that transformational approaches linking action with engagement have more impact than transactional activities
- It appears Australians like sustainable solutions, so the combination of Australian acacias and indigenous knowledge would most likely be engaging for the public.

Frankel, A. (2011)

Trends show that what's called the "participatory approach" (involving people) gains much more traction than the "transactional approach" (asking people for money). When people feel they're part of something they give their support in various forms – volunteering, pro bono work, etc – and that often translates into money or value of some kind. In addition, it appears Australians like sustainable solutions. So linking our acacia work with indigenous knowledge and economic development for the world's poor would most likely be engaging for the public. (Ref 2011)

But it's one thing to have the answers and another to get people on-side. Like Rosemary (Sayer), I would suggest that we have something special here, but in order to bring your research to fruition we need support and that means getting various parts of the community on-side. The question is 'how do we do it'? And that's our task in the focus group of this workshop. With concrete outcomes for a research and development agenda based on the nutrition and agriculture/agronomy issues already discussed here, my hope is that this can be overlayed with a community engagement strategy that will help us to get the support required. Tony (Rinaudo) wants to bed down a 5 year plan – that's our goal.

2. Tell a simple story

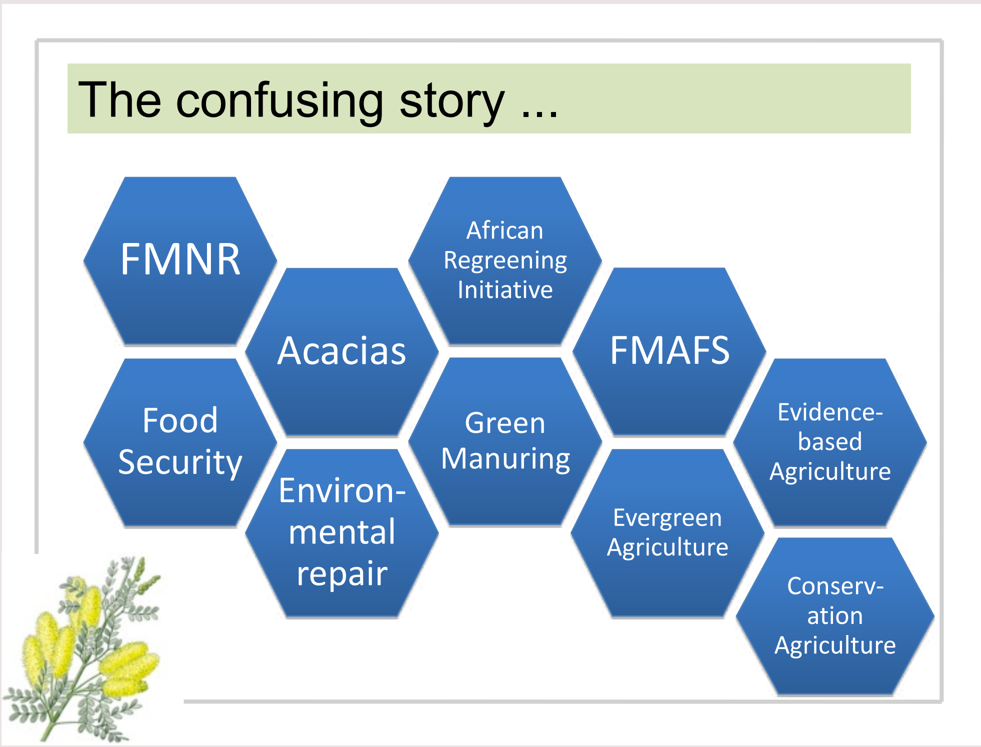
When we're closely and intensely involved in our work, it's often hard to tell people simply about it. But simple stories are the ones that have the most effect – all other things being equal. When I'm confronted by this problem, I try to put the story in some form of context – usually related to the person or people I'm relating the story to (the audience).

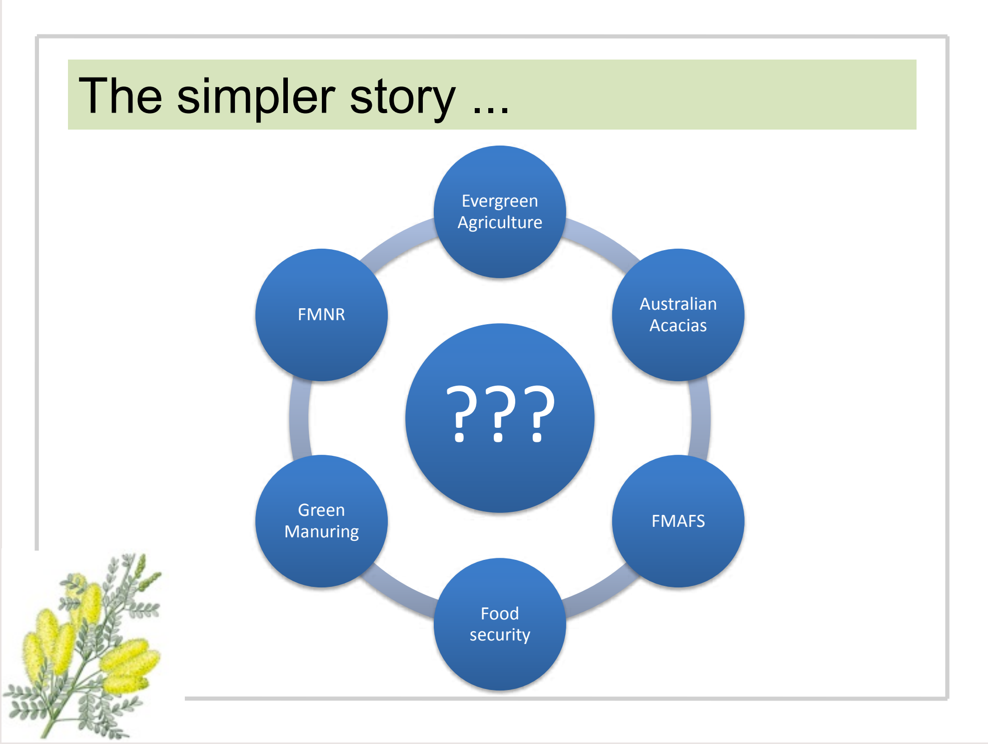
In putting things in context, I often think about the overall structure of what we're doing, or trying to do, and ask some questions.

Tony (Rinaudo) wanted support for his work and as I come from a communications/advocacy/entrepreneurial background with a special interest in agricultural commerce, I was trying to help him. When I started working with him earlier this year, I would get confused by all the acronyms and the number of different people he dealt with across the world. There was FMNR (Farmer Managed Natural Regeneration), FMAFS (Farmer Managed Agro-forestry Farming System), edible acacias, wattle seed, the African Regreening Initiative, Regreening the Sahel, green manuring, Conservation Agriculture, Evergreen Agriculture, evidence-based agriculture, livelihoods, food security ... and then climate change and global warming, which this work can help communities adapt to and mitigate against.

But in my confusion I kept having this bad dream – that I'd end up presenting in a boardroom high up in a Sydney skyscraper blabbering all these confusing acronyms and concepts while the immaculately-dressed and highly-intelligent board members looked at me confused. I would then be ushered out.

I shudder to think that dreams can come true.





In order to tell people a story that will get them interested we need to contextualise our work in simple terms. We work in a sector that's not known for simple communication – we are the only sector that refers to a warm cosy blanket as a "non-food item".

"The more elaborate our means of communication, the less we communicate", said Joseph Priestly (1733-1804). Priestly was an English theologian, dissenting clergyman, philosopher, educator, and political theorist who discovered oxygen, soda water, preached religious tolerance, supported the French Revolution and was run out of town and his house burned to the ground. Life can be tough sometimes – even if you're smart.

And that leads me to the Holy Grail of communication:

Simple messaging
Emotionally engaging
Using common sense

Luckily, Tony took me to Ethiopia and Kenya with him where I saw, first hand, how Australian acacias could assist with food production – both cropping and grazing – timber production and environmental repair. I saw abundant seed – sacks of it – and rejuvenated pastures where livestock had shade from the harsh summer sun. I saw how acacias can bind the land together to stop erosion, protect crops and pastures from parching evaporative winds, and how their falling leaves add organic matter that rejuvenates the soil. I saw how they could be pruned for timber production. At Abreha Atsbeha in Northern Ethiopia, I was told by the locals how the land had been changed from a 'desert' of rocks and dust into highly intensive farming land producing 2 crops a year. I was told how the water table had risen from 12 metres to just two metres and farmers were now forming cooperatives to purchase irrigation equipment. The men, who once went to the cities to find work, which in turn would ruin families, now stayed to work their farms. On top of all that, the baboons – not seen for decades – were back. Nature was returning. People's lives were being transformed.

It's a wonderful story and pretty simple. When I tell people this story they are initially interested because it's Australian. When I tell them about how it fits in with a broader agricultural movement aimed at eliminating famine and helping people make an income large enough to send their kids to school, how the seeds can be used as a porridge for starving babies, fodder for animals, timber for cooking and building, and how it fixes the environment, people's eyes light up. Then I tell them it doesn't cost much, and they're sold.

Like Rosemary says, we have a great story.

The question is do we concentrate solely on the simple message of acacia – someone referred to it last night as "the food tree" – or do we contextualise acacias in the broader framework of food security, economic sustainability and economic repair?

If we opt for the latter, and referring back to the previous diagram, what do we call the inner circle of the diagram? What's the overarching name of what we're doing?

3. Communication is a two-way conversation

In order to create support, we need to start a conversation with a number of different audiences – governments, corporations, bureaucrats, NGOs, the public, researchers, indigenous people – and really importantly people who can influence other people, such as heads of organisations, movers and shakers, broadcasters etc. Everybody in the NGO sector seems to dislike the mega-rating shock-jocks. I say engage them – tell them the story. They might just listen.

Different audiences need different stories told in different "languages" – younger generations communicate differently from older generations, people who listen to commercial radio communicate differently than people who listen to ABC Radio National. Recent research shows that "language" plays an important role (Frankel 2011). "Finding Frames", a recent U.K. report initiated by Oxfam and supported by the Department for International Development (DFID), argues for a fundamental shift in the way global citizenship issues are communicated and understood. (Darnton & Kirk 2011) One of its key findings was the need for a shift in the way we communicate the development message. It included breaking out of a transactional activist model (e.g. sign a petition, donate) towards a participatory model – get people involved.

Frames or Framing is a communications theory that comes out of linguistic theory. In a nutshell it says that language doesn't simply describe reality, but actually shapes reality; and that frames define cultural roles, interaction and behaviour. They even determine our boundaries – what is global and what is our backyard. (Goffman, E 1986)

Here are some examples of framing in the political context. You'll see that they're now regarded as common reality and are emotionally compelling:

- War on Terror – frames foreign policy
- Free market – frames economic policy
- Tax relief – frames policy about the state's role
- Climate change – frames global warming in a way that evokes discussion about consequences rather than causes (Climate change is a bad phrase for us to be using if we actually want to curb global warming) (Frankel 2011; Lakoff 2005)

So, what language and elements of our story would help us? How do we frame what we do?

Maybe we want to get on the top-rating radio show in Australia, or get a public audience or a corporate organisation, or the Foreign Minister on-side? We need to be clear about who we want to engage and why. This means segmenting the market – working out the target audience appropriate to our resources. For example, we could get journalists who are sympathetic to our cause on-side so that the mainstream media starts talking about our work.

A key to developing a successful communications campaign is understanding and early engagement with the target audience's current views (frames) on poverty, citizenship, our backyard, global citizenship and … this work. For example, on returning from Africa with Tony I wrote an article for AusAID about his work. Before that, we weren't talking to AusAID, now we are. The job we have now is to engage them to the next level. But we also need to engage across the community – get people talking about Australian acacias and role they can play in helping fight poverty. The internet and social media can be a big player in this.

It's important that we make the community part of it. People are more likely to be engaged if they feel part of something. Poverty is not fun, but learning about the world, helping people, learning about ourselves and doing good things is engaging and has positive effects on individuals, the Australian community and the world community.

We need a community engagement plan. Let's get one.

References

Darnton, A. & Kirk, M. (2011), *Finding Frames: New ways to engage the UK public in global poverty*, Bond, London.

Frankel, A. (2011), *Public support and engagement with aid in Australia*, presentation at ANCP Community Engagement Workshop held at Oxfam Australia, Melbourne on 12 July 2011.

Goffman, E. (1986), *Frame Analysis: An Essay on the Organization of Experience,* Northeastern University Press, New Hampshire.

Lakoff, G. (2005), *Don't Think of an Elephant! Know Your Values and Frame the Debate*, Chelsea Green Publishing, Vermont.

Recommendations of the Focus Groups

These recommendations summarise the presentations, papers, discussions and findings of each focus group at the workshop as a basis for creating a 5-year research and development plan. Based on this a complimentary community engagement plan. The three focus groups concentrated on nutrition, agriculture/agronomy and community engagement respectively.

Presentations, discussions and focus group discussion focussed on the use of Australian acacias in the Sahelian region of Africa, but contained important inputs from Australia and Chile.

The proceedings of the 1991 workshop asked, "Why develop the seed of Australian acacias as a human food?" (Why not develop indigenous tree and shrub species as seed foods?) It explained that people around the world depend on exotic grain crops, vegetables and livestock – there is no reason why exotic trees and shrubs should not be used as a food source if they appear to have advantages over local species. (House and Harwood 1992)

Advantages of certain Australian dry-zone acacia species as a food source and multi-purpose use in the semi-arid savannah environment of the Sahel include:

- Seed contains high nutritional value.
- Contains low levels of toxic and anti-nutritional values.
- Some species have been a significant part of Australian Aboriginal diets.
- Easy establishment, rapid growth and heavy early seed production compared with African species.
- Foliage of some species not palatable to livestock.
- Seed easily collected and processed using local technology.
- Palatable foods can be prepared by modifying local and other recipes – its main products are flour, seed, porridge and coffee.
- The workshop stressed the multi-purpose use of the acacia – beneficial farming and environmental uses such as windbreaks, building timber, fuelwood production, soil amelioration. These uses have demonstrated increases in crop yields, pasture growth and farm incomes.

Reference

House, A.P.N. and Harwood, C.E. (eds) 1992, *Australian Dry-Zone Acacias for Human Food*, CSIRO Australian Tree Seed Centre, Canberra

Nutrition Focus Group

The Nutrition Focus Group at the Australian Acacias for Food Security Workshop decided on a theme to "Enhance the nutritional status of communities through the incorporation of edible acacia into local diets". In discussion the group identified "What remains to be done?" "How will it be done?" "Who and when?" and "How will it be funded?". It then resolved that the group will write a research proposal.

Participants in the Nutrition Focus Group were:

A/Professor Samson Agboola School of Agricultural and Wine Sciences Charles Sturt University Wagga Wagga, NSW **Professor Steve Adewusi** Dept of Chemistry Obafemi Awolowo University Ile-Ife, Osun State, Nigeria	**Kaitrin Both** Acting Head of Humanitarian & Emergency Affairs World Vision Australia **Dr Victor Owino** Research and Development Manager at Valid Nutrition Nairobi, Kenya **Peter Yates** Rural Sociologist, Farmer and Consultant Victoria

Nutrition group discussion

What remains to be done?

1. Screen different acacias to determine best varieties for food consumption.

How will it be done?	Who and when?	How will it be funded?
Analyse the nutritional profile of different species including anti-nutritional factors and impact on nutritional value of acacia. - Develop minimum chemical thresholds - Develop a quick method for screening key acacias for CEC and CMC - Compare the same variety of Acacia across countries to determine any potential differences in terms of nutrition profile	Steve / Agronomy / Samson? Year 1	Integrated funding with other activities Potential donors: AusAID, Bill Gates, corporates Could be framed: nutrition, climate change, food security

2. Develop best practices for processing selected acacia species to limit anti-nutrient properties in target areas eg: Niger and Ethiopia.

How will it be done?	Who and when?	How will it be funded?
Identify best processing methods - Considering variety of acacia, locally used practices, best practices, sharing lessons across locations eg: Niger to Ethiopia to Chile. - Work with agronomy group to breed for low anti-nutritional factors in selected acacia as needed	Peter Yates / Valid / Agronomy / Samson? Year 1	Integrated funding with other activities Potential donors: AusAID, Bill Gates, corporates Could be framed: nutrition, climate change, food security

3. Develop and evaluate the impact of recipes which can be made at household level using acacia and locally available foods to enhance the local diet of communities in targeted developing countries other then Niger eg: Ethiopia, Chile

How will it be done?	Who and when?	How will it be funded?
Identify best processing methods - Considering variety of acacia, locally used practices, best practices, sharing lessons across locations eg: Niger to Ethiopia to Chile. - Work with agronomy group to breed for low anti-nutritional factors in selected acacia as needed	Peter Yates / Valid / Ethiopia? Year 1–2	Integrated funding with other activities Potential donors: AusAID, Bill Gates, corporates Could be framed: nutrition, climate change, food security

4. Develop a supplementary food product which could be produced using locally available foods plus additional nutrients if needed eg: vitamins and minerals to contribute to reducing malnutrition at times of stress.

How will it be done?	Who and when?	How will it be funded?
	Peter Yates / Valid? Year 3–5	Integrated funding with other activities Potential donors: AusAID, Bill Gates, corporates Could be framed: nutrition, climate change, food security

Additional notes

- Stressed the importance of documenting research undertaken and disseminating this
- To scale-up depends on availability of sufficient supplies of foods such as acacia and Moringa and governments willingness to allow new acacia varieties into countries which haven't had these acacia before. Note this has already been approved by Governments in Niger and Ethiopia

Action points:

- Focal person of each group is to remain in contact with the rest of the group
- Peter Yates is doing a proposal for research that will include some of the research gaps raised in today's workshop
- Plans/proposals/outcomes from each group need to be fed back to Tony by the end of September
- Resources for funding need to be identified where needed.

Nutrition group plan

Overview

It was resolved that the group will write a research proposal, with the major near term outcome of establishing recipes for safe and palatable foods containing processed acacia flour, based on cereals (foods) that are locally produced and consumed in the relevant individual communities in Niger Republic and Ethiopia. A second longer term outcome is the development of an acacia-based weaning food for the most vulnerable in both countries.

It was concluded that the research proposal be:

1. Limited to the first outcome of developing acacia-based staples in Niger and Ethiopia;
2. Part of an overall comprehensive project interlinking the outcomes and objectives of the three major focus groups of agronomy, nutrition and communication;
3. Jointly written by Professor Steve Adewusi and Associate Professor Samson Agboola, with Mr Peter Yates being the coordinator and also providing necessary linkages with World Vision;
4. Available possibly as a stand-alone project for funding from several sources, most likely including AUSaid.

Components of the research project

a. Screening different acacia species such as *A. elacantha*, *A. colei*, *A. tumida* and *A. saligna*, that are currently being adapted to growing conditions in Niger and Ethiopia. This stage of the work is expected to also include other species or subspecies that the Agronomy Focus Group may be selecting which other desirable traits. Screening will be for proximate composition, nutritional profile, protein digestibility, level of anti-nutritional factors such as protease inhibitors, phytates and oxalates, carboxy ethyl and carboxy methyl cysteine.

b. Developing simple processing technologies to improve outcomes in species selected on the basis of results obtained from the screening studies. These may include soaking, roasting, cooking etc., and combinations thereof.

c. Investigating the effect of storage on the proximate composition and nutritional profile of *A. colei* seeds stored under local conditions in Maradi, Niger Republic.

d. Surveying consumption and cooking patterns in respective local communities to identify foods with which processed acacia seed or flour may be compatible.

e. Studying the incorporation of acacia at different levels with the local staples and carrying out model experiments on animals (rats), human intervention studies and sensory evaluation for palatability, acceptability and purchase intent.

f. Developing recipes for safe and palatable acacia-based foods that are acceptable to the local communities in Niger Republic and Ethiopia.

Execution of the project

Tentatively, it was decided that the projects will be based mainly in Africa, with considerable support from Australia. Dr Victor Owino of Valid Nutrition does not think that his company will be interested in this type of project (he will make enquiries nonetheless) but he is personally excited about it and would like to be involved in some capacity. One model that was discussed but not yet confirmed was the use of at least two PhD students to be based mainly in Nigeria (jointly supervised by Profs Adewusi and Agboola) but free to travel and carry out experiments, collecting data from Niger, Ethiopia and Australia as necessary. Once a model was acceptable to all parties involved, it will be possible to develop a research proposal with appropriate budgetary requirements.

Associate Professor Samson Agboola
23/09/2011

Agronomy Focus Group

The Agronomy Focus Group at the Australian Acacias for Food Security Workshop at Alice Springs, Australia, 16–18th August was given the task of identifying new directions for agronomic research and development of Australian acacias and to develop a five year plan, in particular the group led by Dr Daniel Murphy needed to deliver the following outcomes:

1. Identify what needs to be done?
2. Identify who will do it, when and where?

Potential funding sources needed to be identified, but it was proposed that Tony Rinaudo would write up a project proposal for submission to AusAID to encompass: agronomy, nutrition and marketing.

This preliminary report from the Agronomy group aims to summarise some of the main points raised in the discussions and provide a framework for further detailed development of the proposal. Tables outlining *what needs to be done* and *who will be involved* are given below (from Dan Murphy's summaries) together with a list of participants.

Detailed advice, inputs and costings are needed to assist Tony for project design and development.

The group was assisted by the following paper from Dan Murphy.

Participants of the Agronomy Focus Group were:

Assefa Adamasu
Food Security Coordinator
Food Security & Strategic Initiatives Department
World Vision Ethiopia

Peter Cunningham
Agroforestry Consultant
SIMaid Australia / World Vision Australia

Professor Rod Griffin
Honorary Research Associate
School of Plant Science
University of Tasmania

Niguse Hagazi
Natural Resources Management Research and Acacia Project Coordinator
Tigray Agricultural Research Institute
Mekele, Ethiopia

Dr Jane Harbard
Research Assistant
School of Plant Science
University of Tasmania

Dr Chris Harwood
Senior Principal Research Scientist
Ecosystems Sciences
CSIRO

Jon Lambert
Chief Executive Officer
Beyond Susbsistance
Warragul, Victoria

Dr Bruce Maslin
Senior Research Scientist
Department of Environment & Conservation
Western Australia

Jock Morse
Biodiversity Consultant
Tathra, New South Wales

Dr Dan Murphy
Royal Botanic Gardens, Melbourne

Wayne O'Sullivan
Great Western Woodlands Project Director
Wilderness Society
Western Australia

Tony Rinaudo
Natural Resources R&D Advisor
World Vision Australia

Assefa Tofu
Carbon Market Specialist
World Vision International
East Africa

Patricio Rojas Vergara
Instituto Forestal
Ministura de Agricultura
Chile

Agronomy focus group discussion paper

Daniel J. Murphy
Molecular Systematist
Royal Botanic Gardens, Melbourne

The Agronomy Focus Group of the "Wattle we eat for dinner?" workshop in Alice Springs, August 16-19, 2011, will discuss new directions, current issues and previous learnings for the agronomy of Australian Acacia species. The aim of this short document is to provide an initial listing of topics, developed in association with Peter Cunningham and Tony Rinaudo, for the focus group to discuss in more detail during the workshop; it is by no means intended as an exhaustive or exclusive listing but rather as a starting point (anyone is welcome to provide additional topics and I will add these as we go through the workshop and the talks). While mostly this document consists of brief points, there is some additional information given that is intended to guide selected topics. The group may prefer to take the topics provided in a different order and hopefully additional discussion areas will be raised during the workshop. Overall, it is anticipated that the discussion will centre on the issues and research into Acacia species for food and multipurpose use in farm systems, for example, for fuel, timber, land reclamation or any other purpose.

There is also a need to keep in mind that the intended outcomes of this focus group include:

- Identifying what needs to be done?
- Identifying who will do it, when and where?
- Identifying ideas for funding?

Throughout the discussion and workshop it would be valuable for participants to highlight and record relevant literature, including projects involving acacia whether current or past; where these were/are being conducted; and the people involved with acacia agronomy research and their contact details (if known). Providing electronic copies of literature, especially reports or book chapters that may not be easily accessible, would also be of great benefit. The intention is to create a database and bibliography for the agronomy of Australian acacia, forming a resource for current and future workers in this area.

It is suggested that as a first step group members share with the group what their current involvement or interest in acacias is. A major aim of the workshop is to enable people to meet others working on similar problems and facilitate interactions and potential collaborations between people.

Taxonomy

This workshop is focused on Australian acacia species. Firstly, for clear communication we need to define what an Australian acacia is, after recent debate surrounding the name and according to the International Code of Botanical Nomenclature, systematic and taxonomic studies.

Acacia species in use

Discussion of species currently being used.

Table 1: Strengths and weaknesses of currently used acacia species based on experience or other possible sources

Species	Comments on strengths and weaknesses
Acacia colei var. *ileocarpa*	
Acacia tumida	
Acacia torulosa	
Acacia elacantha	
Acacia victoriae	
Acacia coriacea	
Acacia saligna	
Other taxa?	

Research and Development

New species

- What are these (list with assistance of group)?
- What makes these species candidates (traits, environmental preference, and relationship to current useful species)?

Acacia spp. for 150–350 mm zones.

- Why (background)?
- Particular targets for 150–350 mm rainfall zone and how to select these?
- Species and growth trials.
- Particular provenances to be targeted?

Species selection methods. For multi-purpose use in various climatic zones.

- Climate matching.
- Local/traditional knowledge.
- Phylogenetic/taxonomic groups and the use of this research for identifying new species to trial (see Appendix 1)
- Opportunities to re-assess species in light of recent advances in taxonomy, evolutionary (systematic) information and species databasing and mapping information.

Issues around using wild-type Acacia and domestication (see Appendix 2)

- Variability of wild-types and provenances. What is known?
- Selection and breeding.
- Hybrids?

Establishment factors

- Inoculant for semi arid and arid/tropic zone acacias.
- Other issues.

Seed production

- Are there molecular markers for certain traits in Acacia (seed quantity)?

- Breeding and improvement for seed production and other selected traits.
- Other legume research that may be relevant to seed production (e.g. Papilionoids?).

Agronomy and systems

Farming systems.

- Background.
- What are these and where?
- New areas?

How to develop species for reclamation of degraded land.

A. saligna domestication.

Animal fodder.

Honey production.

Timber. Gasson (Kew) and Warrick (UNE) et al. are working on Mimosaceae and Australian acacia wood in New South Wales. This area has been neglected (anyone know about wood samples or collections? CSIRO collection.)

Fuel.

Biomass and nutrient cycling/mulching.

There may be a range of other topics and uses, please raise these ideas.

Risks

Invasiveness

Probably the major risk to future use of acacia is the issue of invasiveness in Acacia species. While in many areas acacia invasiveness has not been reported as an issue, caution must be taken when using or introducing new species because some parts of the world are suffering a burden due to invasive species of acacia. It is better to address this issue in a scientific and precautionary manner than to ignore it.

A recent special issue of the journal *Diversity and Distributions* focused entirely on invasiveness and human-mediated acacia introductions (these papers are currently freely accessible and I will also have copies: http://onlinelibrary.wiley.com/doi/10.1111/ddi.2011.17.issue-5/issuetoc).

Risk assessments for new acacia introductions.

- Recommendations when introducing new species of acacia, Wilson et al. (2011).

Examples of where acacia species have not displayed invasiveness? This would be very valuable to guide models and risk assessments (currently a lack of information).

Acacia saligna

- Has become invasive in a number of places.
- Risk greater in some specific climate zones compared to others?

Life history

- Traits that may lead to greater chance of invasiveness (these traits may also be desirable, i.e. heavy seed production?).

- Currently we lack knowledge generally for reproductive biology of acacia. Little studied, some current projects, e.g. pollination and interactions, but these target very few species. This work needs a collaborative approach. The large number of species of Acacia has previously prevented a comprehensive survey and analysis. See Gibson et al. (2011) for current state of knowledge (volunteers to fill gaps?).

Other risks

Issues associated with uptake?

- Farmers and local communities.
- Criticisms, what are these and are they valid?
- Education.

Pests and diseases?

Unsuccessful species

- What are undesirable traits (may link to invasiveness)?
- List of "deselected" species possible?

Gaps in our state of knowledge

What are constraints?

What are the opportunities?.

Development of GIS database

- including species/accessions of interest
- bioclimatic matching

Breeding systems.

Who, what and where of acacia research (database mentioned above).

Any other ideas?

Set research criteria for the next five years

Hopefully we'll have a follow up conference in five years (and not wait for 20 years). One of the big outcomes of the first conference was a list of research needs to be worked on. Can we comment on the outcomes?

Appendix 1

In the past 20 years there have been many advances in the taxonomic resolution of Acacia including many new taxa described (*Flora of Australia*, Maslin et al. 2001). There has also been an advance in the understanding of the evolutionary relationships of Australian Acacia species, both to other acacias (Luckow et al. 2003) and also within Australian species groups (e.g. Murphy et al. 2010). Some Australian species groups which are possible targets for novel food species were recently studied in detail, including the *Acacia victoriae* group and the *Acacia murrayana* group (Ariati et al. 2006). Alongside these advances there was a large project completed to electronically database and map all Australian plant specimens in Australian herbaria (Australia's Virtual Herbarium). This data is now accessible for detailed biogeographic/bioclimatic mapping of Australian plant species. There is now an opportunity to reasses and use this recent taxonomic, systematic and species database information to further guide acacia species selection and make predictions for further sampling and species trials.

Appendix 2

While there are recent domestications for new crops using woody plants, for example, some tropical fruits, there are relatively few novel legume crops that have been introduced into agriculture in recent decades. An exception is the use of Australian Acacia species in parts of sub-Saharan Africa as a source of human food (e.g. Rinaudo & Cunningham 2008; Yates 2010). Legumes in general have previously been proposed as a model plant family for research into a number of different areas, including food production (e.g. *Plant Physiology* 137:1228-1235 (2005): *Legumes as a Model Plant Family*. http://www.plantphysiol.org/content/137/4/1228., and the legume family possesses a number of characteristics that make it desirable for further investigation. A number of traits make Australian acacia species a potentially good model group in which to investigate the issues and factors surrounding the domestication of new legumes. This information is crucial in the broader agricultural context if the pool of available agricultural species on which humans currently rely is to be increased.

Notes from Agronomy group discussions (adapted from C Harwood)

The group commenced with each member sharing their background, current work and interest/involvement with acacias.

Discussion guidelines

The group decided to separate *A. saligna* from the other candidate species which are grown in semi-arid lowland tropical environments. Ways of organising the discussion were considered, one was to follow stages in the domestication pathway as outlined by Stephen Midgley. Another approach was to focus on knowledge gaps and requirements from the perspective of development practitioners – "demand pull" rather than "science push".

Acacia saligna

Area planted

There are currently approx 15,000 ha of plantations in Chile, with potential for greater expansion. In Ethiopia large areas (>10,000 ha) of spaced trees in enclosure areas in Tigray, Ethiopia.

Production goals/outcomes

What are the production outcomes for *A. saligna*? In Chile – seed for food products? In Ethiopia – timber, fodder, seed, environmental restoration. We need to understand the costs and benefits from growing *A. saligna* for multiple products and services across the range of target landscapes and climates in Ethiopia under different silvicultural management systems (spacing, pruning etc.) so that optimum benefits from the species can be obtained.

What end products are we aiming for? e.g. poles vs multi-purpose/seed. Are different subspecies suited to different end products?

Possible perceived negative effects of *A. saligna* in Ethiopia, which require study, are:

- Negative effect on honey production.
- Weediness/invasive potential.
- Reliance on a monoculture (possible production loss from introducing fungal biocontrol *Uromycladium* from South Africa)
- Short lifespan – can this be extended by silvicultural methods?

Literature review

There is a need to review the existing literature (published and grey) on *A. saligna* with a particular focus on its potential use in Ethiopia. Findings from nearby countries where the species is grown as an exotic are likely to be particularly valuable. Such a review should include collation of the literature, and making it available electronically where possible, but also critical interpretation and review.

Genetic base of *A. saligna*

There is a need to establish the genetic base for *A. saligna* landraces already in use in both Chile and Ethiopia. Which sub-species and provenances are being grown? Reliable and comparative methodology needs to be applied to investigate what sub-species are present in each country and the within landrace variability. There may need to be a breeding program if the genetic base is found to be to narrow? This was the perception in Chile.

Provenance trials with a range of sub-species and seedlots need to be established in target zones in Ethiopia and Chile with local/adapted landrace types for comparison.

Nutritional value: seeds/forage

The nutritional value of the seeds and any associated genetic variation in this value needs to be completed in Ethiopia and Chile.

We must always keep under review whether other tree species (such as *Moringa oleifera*, for example), could deliver better livelihood outcomes than the Acacia species under investigation.

Acacia species for the arid/semi arid tropics

In the Sahel (semi-arid lowland tropics, West Africa) the species already identified and developed for multi-purpose use are *Acacia colei, A. tumida* and *A. torulosa*. These species have been developed in the Maradi region of Niger for use in the 450–550 mm rainfall zones. However, in years with less than 350 mm annual rainfall, which are now becoming more frequent, these species are producing low/no seed yield. In a drying climate, what can be done?

Two parallel approaches were discussed:

1. By selecting and breeding within the currently introduced and used species, and by optimising their silvicultural management (spacing, coppicing, pruning, position in the landscape, use of water-harvesting systems to direct run-off onto trees) we may be able to improve seed yields.
2. There may be other acacia species and provenances which could be introduced to Sahelian countries that would give more reliable seed production in dry years. Re-assessment of early trial results in Sahelian countries might identify such species. Re-examination of candidate species in their natural Australian environments might also help. Are there species that seed annually, even in drought years? Would there be trade-offs of lower biomass production, and lower seed yields during average and above-average years?

Deeper-rooted acacia species (*Acacia victoriae* is a possibility) may hold more prospect of reliable food production in drought years than shallow-rooted species.

Adoption

Even after 20 years of development and promotion, adoption has been very slow and generally confined to the Maradi region.

What limits uptake? Is it agronomic limits to seed production, or is it lack of interest in eating the seeds? Can development of a cash market for the seeds stimulate demand and hence adoption/use.

All acacia species

Multi-purpose

Viewing acacia species as multi-purpose rather than solely focusing on acacia seed as a potential food source was generally agreed as the best way forward.

Inoculation requirements:

Acacia species are nitrogen fixing legumes and should always be considered with their root nodule symbionts. There are examples of poor nodulation of *A. tumida* in nurseries in Niger. Inoculants should be produced and made available for all nursery plantings of acacias. When collecting seed in the natural range, nodules should also be collected and Rhizobium strains isolated. It may be possible to develop mixes of strains that will suit a number of Acacia species, as has been done for southern Australian species by Dr Peter Thrall of CSIRO.

Social/cultural context

The social context of acacia use must be considered and there needs to be training for people establishing and managing acacia plantings.

Cultivar maintenance

It is essential to develop effective seed and seedling supply systems which ensure the maintenance of superior varieties, either superior introduced provenances or selected land races.

Markets

There is need for business development training to support the development of commercial seed-to-food supply chains.

Networking

We need to identify networking partners including farmers, private partners, technical centers, commercial firms and universities.

Table 1: Tasks and human resources for R & D: *A. saligna*

What needs to be done?	Funding sources?	Who will do it?
Priority 1. Risk management plan for *A. saligna* and any acacia species to address potential invasiveness. Cost/benefit approach Monitoring built into new planting and introductions.	World Vision, AUSAID	Rob Francis Wayne O'Sullivan Patricio Rojas Niguse Hagazi Dan Murphy
1. Research Plan for *A. saligna:* Ethiopia, Chile	World Vision, AUSAID	Peter Cunningham (co-coordinator) Wayne O'Sullivan Bruce Maslin Niguse Hagazi Patricio Rojas Jon Lambert Jock Morse Contractor?
2. Research project to assemble and review literature on *A. saligna* (3–6 months).	World Vision, AUSAID	Contractor? Bruce Maslin Wayne O'Sullivan Niguse Hagazi Patricio Rojas
3. Research project to identify landraces, subspecies of *A. saligna* currently in use and assess adequacy of material. (Ethiopia, Chile)	In progress-WVA project (Ethiopia) TARI, AUSAID, Australian-Chilean collaboration, INFOR (Chile)	Peter Cunningham Bruce Maslin Wayne O'Sullivan Niguse Hagazi Patricio Rojas
4. Research production systems for different products • Produce methodology for multi-purpose or specific uses • Site & community specific requirements • Silvicultural trials	World Vision, AUSAID Australian-Chilean collaboration, INFOR (Chile)	Peter Cunningham Jon Lambert Niguse Hagazi Patricio Rojas
5. Exchange visits, Chile, Ethiopia	World Vision, AUSAID Australian-Chilean collaboration, INFOR (Chile)	Niguse Hagazi Patricio Rojas

Table 2: Tasks and human resources for R & D: Sahelian- arid/semi-arid tropics Acacias.

What needs to be done?	Funding sources?	Who will do it?
1. Research plan for assessment of existing species in use in the Sahel (*A. colei, A. torulosa, A. tumida*) Review data from species trials. • Aim to maximise seed yields from existing species/germplasm • Secure quality seed supply	World Vision AUSAID	Peter Cunningham Chris Harwood Rod Griffin
2. Research other potential species/ germplasm and previous candidates in light of climate change	World Vision AUSAID	Bruce Maslin Jock Morse Chris Harwood Peter Cunningham
3. Rhizobium inoculants – Research & development	World Vision AUSAID	Peter Thrall (CSIRO) Peter Cunningham
4. Market process – Seed to food. Strategies and practice	World Vision AUSAID	Nutrition group

Community engagement

Background

At Alice Springs during August 2011, the *Australian Acacias for Food Security* workshop was held to re-ignite work that has been carried out over the last twenty years in Africa and Australia.

One of the three working groups was a Community Engagement Focus Group (incl. communications and marketing) that identified that no clear long term communications strategy or plan existed to engage the Australian community.

Participants in the Community Engagement Focus Group were:

Ross Britton Projects Director SIMaid Australia	**Rob Francis** Community Projects Manager World Vision Australia
Jason Brooks Country Director for Niger Adventist Development and Relief Agency International	**Belay Haddis** Economic Development Department Manager World Vision Ethiopia
Esther Brueggemeier Proprietor, Wild About Wattle Group Leader and Seed Bank Curator, Acacia Study Group	**Viv Mancusi** Program Support Officer Humanitarian & Emergency Affairs World Vision Australia
Johannes Brueggemeier Wild About Wattle	**Rosemary Sayer** International Communications Specialist Perth, Western Australia
Seigland D'Arcy Managing Director. adeal Altona North, Victoria	

Recommendations

The group made four key recommendations regarding community engagement, communications and marketing of the initiative.

1. It was agreed to develop a long-term, sustained communications plan to engage the Australian community. It was agreed there is an urgent need to engage Australians about the wattle story in Africa. Our goal is to raise awareness and attract "buy-in, involvement and donor support". It will be built on pride and the concept of giving a hand-up, not a hand-out in African countries.
3. It was agreed "the wattle project and work" needs to be named and branded.
4. The communications plan will be developed in close association with the agronomy and nutrition groups' needs. It must also build on what has already been achieved.
5. It was identified and agreed that more needs to be done to engage African communities. (It was noted this may fall outside the scope of this work. For further consideration.)

Discussion and brainstorming

Energy and excitement don't create clear communication

- There are twenty years of extraordinary research and results where the use of Australian acacias has made a difference to the quality of life in various communities in Sahelian Africa.
- This is a great story to tell – we have just never told it very often or very well.
- Sometimes grand visions and agendas create energy and excitement, but they can also cause confusion and fragmentation because there are no clear messages – even when we think we are driving towards the same goal.
- The acacia workshop gave us all the opportunity to come together, reflect and re focus.

Translate project goals into communication goals

- The overall acacia programme goals must become the main reference for a new communications and community engagement programme.
- We aim to use the acacia workshop as a starting point to gather past material, stories and results to develop the communications plan, as well as communicating the new way forward for the project.
- We will continually liaise with Tony Rinaudo and the Agriculture/Agronomy and Nutrition groups to develop and update the communications goals.

Australian communications plan

- We will appoint a consultant to take these goals and develop them into a strategic communication plan to be circulated by 1 December, 2011.
- The plan will re-package and re-focus the acacia project work ready for re-launch at a date to be decided in 2012.
- Famine prevention is top of mind now – the time is right to relaunch 20 years of innovation.
- Members of the Community Engagement Focus Group will input to the plan along with Tony Rinaudo and other key stakeholders from the workshop.

The preparation and plan should:

- Assemble all the relevant material to date.
- Develop strategies and actions to communicate about wattles in Africa – a great Australian story.
- Develop strategies and actions to communicate the way forward.
- Understand from the agronomy and nutrition groups what is the future for wattles in Africa? Where our work will focus?
- Research and SWOT
- Overall communications goals
- Communications objectives
- Stakeholder mapping and messaging
- Strategies
- Actions
- Two year timeline
- Measurement and evaluation processes
- Budget

Who do we need to engage in Australia?

- Influencers
- Indigenous people
- NGOs
- Community groups
- Business, industry and professional groups (eg. CEDA), Chambers of Commerce, AICD
- Media
- Government and politicians
- Celebrities
- Universities & research organisations – agricultural scientists, nutritionists, relevant faculties and students
- Corporations
- SMEs
- The Public

Name and brand the wattle work

We will appoint an expert branding consultancy to develop a simple, engaging name/brand. It needs to include:

1. Australian acacias/wattles
2. Connecting communities
3. An empowering program – a step-up not a hand-out
4. The combination of wattles and indigenous knowledge is a winner in Australia
5. The word “seed” was preferred by African colleagues as it implied promise and growth
6. Multi-purpose seed/tree that has many different uses

Initial branding ideas:

- Make Australian acacias tangible
- Famine prevention – time is right to re-launch 20 years of innovation
- Multi-purpose tree – not just a seed
- Success stories (before and after)
- Participation in the story
- Engage stakeholders and make them part of the journey
- Emotional connection
- Feedback mechanism

Africa communications plan

It became clear during the workshop that a more strategic approach to communications/change management and adoption was also required in African countries

Discussion revealed this engagement needed to be different in each country, but three overarching strategies were needed to:

- Convince people in the communities
- Convince governments
- Educate/change behaviour

Convince the people

- The Niger program has been community driven. Are there learnings that may be transferred to Ethiopia?
- The Ethiopian program has been government driven. Are there learnings that can transferred?
- The Wattle program needs a name that travels across countries, but is also local
- Continue to demonstrate economic viability and deal with short term losses if they occur (different in each country)
- Develop centres for farmers in each country
- Set up better ways to exchange best practice models

Convince governments

- What can be learnt from the Ethiopian experience?
- Environmental story, not a crop/food story.
- Look for more success stories that can be shared and replicated
- Find ways to introduce partnerships in govt between Niger and Ethiopia

Extend education program and resources

- Needs to be much more compelling story – not just the seed story – long-lasting, fuel, charcoal, environment, construction
- Don't re-invent wheel. Get the story right and use it. Give people in the field simple messages that are consistent to tell the whole story
- In Ethiopia we understand and can see the environmental story, but not the rest of the acacia story – need pictures, stories, evidence, proof
- Use elders, social and religious leaders to communicate messages – these are influencers too, not just farmers groups

Schedule

Month	Activity	Budget
Nov 2011	Appoint consultant to develop two year Aust community engagement and communications plan (includes liaison with working groups and meets with Tony Rinaudo and Rob Francis)	$3,000
TBA	Appoint branding/advertising agency to develop brand and name for work in Australia	$TBA
	Provide assistance to African team for communication plans	$TBA
	Feedback to CE&C Plan and revise	
	Finalisation of CE&C Plan Detailed calendar of activities developed for 2012 and 2013	
	Half-day media training /key message workshop for Tony Rinaudo and any other identified spokespeople for acacia program in Australia (Use World Vision camera camera crew to keep costs down)	$1,500
	Development of all materials, media kits, backgrounders pix, website, etc. for major re-launch of wattle work	$TBA
	Find a hook Major launch/re-launch	$TBA