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Full Length Research Paper

An overview of the trend and status of food science and technology research in Zimbabwe over a period of 30 years

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In Zimbabwe there has been considerable research in food science and technology on the local foods ranging from fermented foods and beverages to fruits and vegetables. This paper reviews for the first time the status and trends in food science and technology research in Zimbabwe during the past 30 years. Some of the notable original research findings from these researches are summarised, highlighting the status and development thereof and serving as guidance to scientists on what needs to be investigated further, for partnerships and for those who wish to develop the products to commercial products. An attempt is made to pinpoint significant research gaps, and the applications of the research in critically reviewing the research. Significant research has been covered in fermented milk, sorghum based foods and fruits. There has been work on the microbiology and biochemical changes from naturally fermented milks of Zimbabwe. The abundance of polyphenol-rich sorghums has sparked interest of food scientists in investigating effective methods of processing the available varieties so as to improve the acceptance and utilisation of sorghum for food and overall food security in Zimbabwe. The potential antioxidant properties of phenolic acids found in indigenous fruits of Zimbabwe has stimulated research and there are reports of good antioxidant activities from some Zimbabwean fruits. There is little published information in scientific journals on the nutritional composition of the indigenous and traditional fruits and vegetables and other foods of Zimbabwe.

Key words: Traditional foods, fermented foods, fruits and vegetables, research, Zimbabwe.

INTRODUCTION

Food technology is the application of food science to the selection, preservation, processing, packaging, distribution and use of safe, nutritious, and wholesome food. Modern food science and technology has much to contribute to helping the food-deficit nations eat adequately. It can help us when we examine local problems in terms of the use and improvement of local technologies which are often quite sophisticated and the result of centuries of development. This review aims to summarise, for the first time, the application of scientific knowledge in food science and technology to Zimbabwean food products and problems and making them more adaptable to the conditions that exist in a developing country like Zimbabwe. This paper highlights the adaption and adoption of food science technologies to locally available resources and local circumstances.

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Resource inventory of indigenous and traditional foods and food composition table of Zimbabwe

In Zimbabwe food science and technology research probably began by the publication of a resource inventory of the indigenous and traditional foods in Zimbabwe by Gomez (1988). The importance of indigenous and traditional foods in food security and nutrition of local people cannot be overemphasized. These foods resources have been adapted over several years to the food habits, tastes and needs of traditional communities and to the agro-ecological conditions where they are found. This resource inventory of the indigenous and traditional foods of Zimbabwe was a good attempt to identify and collate many of the foods of Zimbabwe for planning conservation and improvement strategies. The resource is representative of the variety, diversity and range of food resources of Zimbabwe, although it is not a complete or comprehensive listing of traditional foods of Zimbabwe. The inventory simply lists the food item by its English name, local (Shona and Ndebele), and scientific name and briefly describe its preparation and use.

The next important publication in early food science and technology research was the nutritive value of foods of Zimbabwe by Chitsiku (1989). The table of nutrient composition of foods commonly used in Zimbabwe which was presented was developed from data in various markets, surveys, technical and scientific reports and journals. This was the first attempt to establish a table of nutrient composition of the foods of Zimbabwe, data of which is used by research nutritionist to assess the nutritional supply of a nation's food supply. The data is also used by dieticians, physicians, government and non-government agencies for various reasons. A food was identified by its scientific name and its source and variety identified. For cooked foods, the methods of cooking, temperature used and length of cooking time were noted. The food groups were selected and arranged as: grains and grain products, eggs, fats and oils, meat, poultry and edible insects, fish, vegetables and vegetable products, fruit, nuts and seeds, sugars and syrups and beverages. The nutrients for the Food Composition Table were: energy, total carbohydrate, total fat, protein, water, calcium, iron, sodium, potassium, phosphorus, thiamine, riboflavin, niacin, folic acid, vitamin B12 and ascorbic acid. However, there are a number of gaps in nutrients of some foods which should be filled by appropriate analysis of the food. Information is needed on the nutritional value of processed, cooked and home-prepared foods of Zimbabwe. There is need a need to carry out a proper amino acid composition of the foods to know the quantity of essential and non-essential amino acids present. Equally, there is need to know the fatty acid composition of the fats and oils. Micronutrients are now very important in nutrition and health and there is need to identify and quantify these from the foods of Zimbabwe.

Traditional fermented foods and beverages of Zimbabwe

Food biotechnology, as we know it toady, is rooted in the development of fermented foods early in civilisation. Fermentation is a widely practised ancient technology for preparing and preserving food, especially cereals, milk, fish and oil seeds and fermented foods are an essential part of diets in all regions of the world. Traditional fermented foods are those that are indigenous to a particular area and have been developed by the local people using old-age techniques and locally available raw materials. Traditional recipes are handed down through generations are still used in processing food in Zimbabwe. However, the country cannot continue to depend on historical methods of food processing. Traditional fermentation processes and the potential for their modernisation are increasingly attracting the attention of scientists and policy makers as a vital tool of food and nutrition security strategies and commercial use. Several traditional fermented foods and beverages are produced at household level in Zimbabwe from various local raw materials. These include fermented maize porridges (*mutwiwa*, and *ilambazi lokubilisa*), fermented milk products (*hodzeko* and *amasi*), non-alcoholic cereal-based beverages (mahewu, tobwa and mangisi), alcoholic beverages (*doro / uthwala* and *chikokiyana*), distilled spirits (*kachasu*) and fermented fruit beverages (*mukumbi*). Gadaga et al. (1999) reviewed well the published research (list up to 1999) and production processes common of Zimbabwean traditional fermented foods. They also highlighted, where possible, some of the microbiological and biochemical properties of the fermented foods and technological improvements that had been achieved on the production of some of the foods. In this paper, the focus is on the research on traditional fermented foods from the year 2000 to present.

Fermented milk

Fermented milk products (*hodzeko* and *amasi*) still play an important role in the diets of the people of Zimbabwe. More research has been carried out to unravel the microbiological and biochemical changes in the pro-duction of the fermented milk products in Zimbabwe since the review by Gadaga et al. (1999). There is an increasing interest in the role of yeasts in dairy fermen-tation since they always grow together with lactic acid bacteria (Jakobsen and Narvhus, 1996). Yeasts and moulds were considered as undesirable and a sign of poor hygiene in previous studies (Mutukumira, 1995). However, the yeasts could be important and essential part of the mixed microflora involved in the natural fermentation process of the milk. Gadaga et al. (2000) made a study to enumerate and identify yeasts isolated from Zimbabwean traditional fermented *amasi* milk samples. The dominant yeasts identified were *Saccharomyces cerevisiae* isolates, *Candida lustaniae* isolates, *C. colliculosa* isolates and *S. dairenensis* isolates with counts ranging from <2 to 8 log cfu g-1. The study concluded that the *amasi* samples contained a wide variety of yeasts with a few dominant species which could contribute to the characteristics of the milk in the fermentation process. However, it must be noted that the high number of colony forming units does not necessarily means dominancy of the complex biochemical processes in the mixed fermentation system.

The growth and interaction of yeasts and lactic acid bacteria isolated from Zimbabwean naturally fermented milk in UHT milk was investigated by Gadaga et al. (2001a). Both single and yeast-lactic acid bacteria co-cultures of various subspecies of *Lactococcus lactis, Lactobacillus paracasei*, and *Candida* species, and *S. cerevisiae* were investigated using UHT milk. From the observations done, it was concluded that *Candida kefyr* 23 grew well in UHT milk producing volatile organic compounds that may be important to the flavour profile of the fermented milk. The enhanced production of some flavour compounds such as acetaldehyde and malty compounds in some yeast-Lactic acid bacteria co-cultures was presumed to be indicative of interaction between the micro-organisms. Similar results and conclusions were also made after investigating the use of yeasts, lactic acid bacteria and their combinations as starter cultures in milk compared with naturally fermented milk (Gadaga et al., 2001b; Gadaga et al., 2007; Narvhus and Gadaga, 2003).

Evaluation of the microbial safety of fermented foods involves deliberate inoculation with a number of pathogens. The survival and growth of *Escherichia coli* 3339 and *Salmonella enteritidis* 949575 isolated from human clinical samples, in milk fermented with lactic acid bacteria and yeast strains previously isolated from Zimbabwean naturally fermented milk was studied by Mufandaedza et al. (2006). The starter cultures used were *L. lactis* subsp. *lactis biovar. diacetylactis* alone or in combination with *C. kefyr* 23. The lactic acid bacteria alone or in combination with the yeast significantly inhibited the growth of the pathogens. Addition of yeast to milk fermented by the lactic acid bacteria did not enhance or diminish the inhibitory capacity of the lactic acid bacteria. The lactic acid bacteria were concluded to offer protection against the pathogens due to its fast acid production which resulted in rapid pH reduction. The occurrence of pathogenic bacteria in raw milk, cultured pasteurised milk and naturally soured milk produced at three small-scale dairies in Zimbabwe was determined by Gran et al. (2003). Mean levels of *E. coli* in raw milk, cultured pasteurised milk, and naturally soured raw milk were 4.5, 7.1 and 7.8 $\log_{10}$ cfu ml^{-1}, respectively. Enterotoxigenic *E. coli* which produce heat-stable enterotoxin were found in 16 of the samples and *Staphylococcus aureus* was also identified in all the milk products in high numbers. The high numbers of *S. aureus*, *E. coli* and Enterotoxigenic *E. coli* and other pathogenic micro-organisms found in pasteurised and unpasteurised milk products represent a health hazard to the consumers and the need for improved hygiene practice at all levels in the dairy cannot be overemphasised.

The hygienic practices during milking and the microbiological quality of the milk at the farm and on delivery at three smallholder dairies in Zimbabwe were studied by Gran et al. (2002a). Petrifilm™ was used for the determination of *E. coli*, coliforms and aerobic mesophilic count. Using aerobic mesophilic counts Petrifilms as contact plates, 83% of the utensils used for milk production had >300 cfu per 20 cm^2. Of the milk samples at the farm, 95% had *E. coli* counts < 10^1 cfu ml^{-1}, and all had aerobic mesophilic counts <10^5 cfu ml^{-1}. The aerobic mesophilic count increased on delivery depending on delivery time. The water quality, unsatisfactory cleaning of utensils and milking practice should be improved at these dairies. Microbiological quality and hygienic practice during the production of naturally sour milk made of unpasteurised milk and cultured milk of pasteurised milk, were studied at the three smallholder dairies in Zimbabwe (Gran et al., 2002b). Petrifilm™ was used for the determination of *E. coli*, coliforms and aerobic mesophilic count. Aerobic mesophilic counts Petrifilms used as contact plates showed that 52% of utensils at the dairies were not acceptably clean with more than 100 cfu per 20 cm^2. *E. coli* was prevalent in samples of naturally sour milk and cultured milk. The high numbers of *E. coli* found in pasteurised milk emphasized the improved hygiene practice at the dairies. These two studies, however, did not cover the personal hygiene of the workers which is an important source of contamination. There is need for a follow-up research covering the personal hygiene probably after a training course in hygiene.

In Zimbabwe, many communities produce and consume naturally fermented milk called *amasi* from unpasteurised bovine milk. Fermentation is dominated by lactic acid bacteria especially strains of *Lactobacillus plantarum*, *L. lactis, Leuconostoc lactis, Leuconostoc mesenteroides*, *Lactobacillus helveticus, Lactobacillus casei*, and *Lactobacillus delbrueckii*. Lactic acid bacteria (LABs) are known for their production of antimicrobial compounds including bacteriocins and peptides. The study of bacteriocins and their antimicrobial properties is of interest because of their potential as food presservatives. Todorov et al. (2007) studied the production of bacteriocin AMA-K by *Lactobacillus plantarum* AMA-K isolated from *amasi* in Zimbabwe. The cell-free supernatant containing bacteriocin AMA-K inhibited the growth of *Listeria innocua* and *Enterococcus faecalis*. Based on tricine-SDS-PAGE (sodium dodecyl sulfate polyacrylamide gel electrophoresis), bacteriocin AMA-K is 2.9 kDa in size and activity levels of 12800 AU/ml were recorded in MRS (de Man Rogosa and Sharpe) broth at 30 and 37°C. Bacteriocin AMA-K remained stable after 2 h of incubation at pH 2.0 to 12.0 and at 100°C. *L. plantarum* AMA-K grows in milk, but produces only 800 AU bacteriocin per ml after 24 h. Mugochi et al. (2001) developed a bioassay method for the rapid detection of bacteriocins in fermentation broth by detecting the efflux of K^+ ions from a bacteriocin-sensitive indicator strain. Bacteriocins produced by lactic acid bacteria display antimicrobial activity against species that are closely related to the producing strain and maybe other species beyond the same ecological niche. A simple bioassay that can easily detect the efflux of potassium ions from the bacteriocin-sensitive organism could easily indicate the presence of a bacteriocin. Mugochi et al. (2001) used a bacteriocin-producing strain *Lactobacillus lactis* isolated from Zimbabwean sorghum malt and bacteriocin-sensitive *Lactobacillus* L24 strain. There was a rapid increase in concentration of K^+ ions in the medium from approximately 1.6 to 9.5 mM when the crude bacteriocin was added to the sensitive strain. A bacteriocin activity of 8.25 AU per ml produced the lowest detectable concentration of K^+ ions (0.179 mM) and the smallest inhibition zone. The smallest cell dry mass of the indicator strain capable of releasing a detectable level of K^+ ions (0.102 mM) was 0.76 mg. Detection of the bacteriocin by measuring the efflux of K^+ ions compared well with the conventional agar well diffusion assay. Low activities of the bacteriocin and low amounts of the sensitive indicator strain biomass can be used with this bio-analytical system.

Sorghum-based foods and fermented beverages

Sorghum is one of the most important crops grown in many semi-arid and tropical parts of Africa, Asia and Latin America. Among important biochemical components for sorghum processing are levels of phenolic compounds, levels of starch and starch depolymerising enzymes. In Zimbabwe, there have some research methods of processing sorghum with the objective of improving the acceptance and utilisation of sorghum for food as well as overall food security. Phenolic compounds including phenolic acids, flavonoids, flavanols and proanthocyanidins (polymeric flavanols, also referred to as condensed tannins) are secondary plant metabolites naturally present in cereals and other plants and are non-nutritive components (Beta et al., 1999; Bvochora et al., 1999; Nyamambi et al., 2000). Agronomically, the presence of phenolics is associated with diminished pre-harvest losses due to bird predation and post-harvest losses due to storage pests. Varieties (DC-75, *Mutode* and *Chirimaugute*) contain high phenolic contents and represent a fourth of the sorghums widely grown in Zimbabwe. These high tannin sorghum varieties are preferred by some industrial sorghum maltsters and other sorghum users since they accumulate higher levels of reducing sugars and free amino acids than tannin-free sorghum varieties; and are also more resistant to mould infection during malting. However, tannins bind proteins, carbohydrates and minerals, thereby affecting the nutritional and functional value of the bound constituents. Phenolics may also impart undesirable colours in grain products during food processing. Recent investigations in Zimbabwe using sorghum grains have focussed on examining the types and levels of phenolic compounds and effective methods of processing tannin-rich sorghums.

In Zimbabwe and elsewhere in southern Africa, sorghum is milled to produce flours for use in porridges. It is also malted for the production of opaque beer and non-alcoholic beverages. Sorghum varieties vary significantly in kernel characteristics and condensed tannins in the pigmented testa layer. Beta et al. (1999) evaluated the physical and chemical attributes of the most important local Zimbabwean 16 sorghum varieties in terms of their levels of phenolic compounds and kernel properties. Varieties DC-75, *Mutode* and *Chirimaugute* had the highest levels of condensed tannins. No significant varieties were found in 13 varieties. Phenolic content was related to pericarp colour and endosperm texture was not correlated with phenolic compounds. The conclusion of this study was that Zimbabwean sorghums lacked ideal agronomic and processing physico-chemical characteristics defined in terms of high polyphenols, plus hard endosperm and thin pericarp and research was required to develop effective methods to process the local polyphenol-rich sorghums.

In this regard, Bvochora et al. (1999) investigated the effect of fermentation processes on proanthocyanidins in sorghum during the preparation of *mahewu*, a non-alcoholic beverage. They also investigated the effect of type of sorghum cultivar on the fermentation pattern of *mahewu* and growth of micro-organisms responsible for the spontaneous acidic fermentation of the product. They followed the changes in proanthocyanidins (PA), total phenol, reducing sugar, amylase enzyme and free α-amino nitrogen (FAN) during malting and fermentation. During malting of the grain cultivars decreases of soluble PAs were 48 and 59% in DC-75 and Mutode, respectively, while initial PAs were very low and became negligible for *Chihumani* and SV-2 cultivars. Accumulation of reducing sugars, FAN and amylase activity were considerably higher for DC75 and *Mutode* as compared to *Chihumani* and SV-2 during the germination period suggestion that the development of these constituents were not correlated with total phenol levels. Decreases in water soluble PAs during fermentation were 54 and 63% for cultivars DC-75 and *Mutode*, respectively. Also differences in fermentation characteristics were observed between red and white sorghum cultivars. It was concluded that malting and lactic acid fermentation of high PA containing sorghum cultivars resulted in a decrease in the levels of PAs. The PAs impart an astringent or bitter taste to mahewu and the decrease in soluble PAs associated with malting and fermentation make the product more palatable.

The major commercial use of sorghum in Zimbabwe is in the industrial brewing of sorghum opaque beer, where a high polyphenol sorghum cultivar DC-75 is a major ingredient. Bvochora et al. (2005) studied the variation of sorghum phenolic compounds at various stages during the preparation of opaque beer. The stages of traditional opaque beer preparation involve the cooking of cereal meal; lactic acid fermentation; boiling of the lactic acid fermented mixture; first alcoholic fermentation; addition of sweet, non-alcoholic beverage (masvusvu); straining; and the second alcoholic fermentation stages. Decreases in the levels of proanthocyanidins were 52 and 34% during the lactic acid and second alcoholic fermentation stages, respectively. The main low molecular weight phenolic compounds detected in sorghum malt were ρ-hydroxybenzaldehyde and ρ-hydroxybenzol alcohol. Levels ofρ-hydroxybenzaldehyde decreased during both lactic acid and alcoholic fermentation while the levels of ρ-hydroxybenzoic acid and ρ-hydroxybenzol alcohol increased during alcoholic fermentation. The study of phenolic compounds in beer is important as they are involved in flavour characteristics, foam maintenance, physical and chemical stability and shelf life of the beer (De Stefano and Montanari, 1996).

Ethanol production by fermentation of sweet-stem sorghum juice using *Saccharomyces* yeast strains from various sources was investigated by Bulawayo et al. (1996). S. strains Vin 7, SB9, N96 and GSL had more than 85% sugar conversion efficiencies. Sweet-stem sorghum is a potentially good alternative crop to sugar cane for ethanol production. Bvochora et al. (2000) applied very high gravity technology to the co-fermentation of sweet stem sorghum juice and sorghum grain and reported levels of ethanol three times higher than the levels under normal fermentation conditions. The technology involves preparation and fermentation of mashes containing 300 or more grams of dissolved solids per litre compared to 11 - 12% dissolved solids in normal fermentation (Thomas et al., 1993). This creates an opportunity for process improvements in the conversion of biomass to fuel alcohol which would result in more favourable production economics. Very high gravity fermentation is a process improvement aimed at increasing both the rate of fermentation and ethanol concentration. An independent and secure source of liquid fuel is seen as a sensible strategy because of Zimbabwe's geographical position, its politically vulnerable situation and foreign-exchange limitations, and for other economic considerations.

There have been research efforts to apply very high gravity technology to the brewing of Zimbabwean traditional opaque beer by Bvochora and Zvauya (2001). In traditional brewing, worts of 11 - 12% dissolved solids are fermented to produce beers of 4 - 5% alcohol. Three types of opaque beer were produced, differentiated according to the varieties and ratios of raw materials used in the initial stage of beer preparation. Beer 1 contained sorghum meal and sorghum malt in the ratio 2:1, beer 2 contained sorghum meal and finger millet malt in the ratio 2:1 and beer 3 contained sorghum meal, maize meal and finger millet malt in the ration 1:2:2. The beers 1, 2, and 3 were prepared under normal and high gravity (HG) fermentation conditions. The pH values of the brews and dissolved solid content decreased during the preparation process for all beers although the time taken to attain the desired sourness and final products varied according to the raw materials used for the beers. High ethanol levels were obtained for the HG beers compared with the normal beers, the maximum ethanol level recorded being 4.7% (v/v) for HG beer 3. A sensory evaluation carried out to assess the overall acceptability of the beers revealed HG beers 2 and 3 as having the highest overall acceptability of 82% while HG beer 1 was the least accepted.

Dlamini et al. (2007) investigated the effect of sorghum type and processing on the antioxidant properties of African sorghum-based foods on total phenols, tannin content and antioxidant activity. The products were prepared by fermentation, conventional and extrusion cooking of the whole and decorticated ground grain. The tannin sorghum types had higher 2,2'-azino-bis(3-ethylbenzthiazoline-6-sulphonic acid) or ABTS and 2,2-Diphenyl-1-Picrylhydrazyl or DPPH antioxidant activities compared to the cultivars without tannins. Antioxidant activity was significantly correlated with total phenols and tannins. Processing generally decreased antioxidant activity, however, conventionally cooked porridges had higher antioxidant activity than the extrusion cooked products. The retention of antioxidant activity, particularly in fermented and unfermented porridges, meant that whole tannin sorghum can be processed into foods with potential health benefits. This brings the question of antinutritive and antioxidant properties sorghum varieties with high tannins which needs to be addressed. The role of phenolic compounds in cereal grains as antioxidants or antinutritive is not definitive in processed foods.

Malts are cereals that have been steeped, germinated and kilned under controlled conditions. Barley is traditionally the cereal of choice for malting, however, barley cultivation in tropical areas has not been successful. Thus the production of beer and malted foods requires the importation of barley malt from temperate regions or the utilisation of tropical cereals for germination and malting. There have been research efforts to a better understanding of the malting characteristics of sorghum cultivars in Zimbabwe. Malting properties of 16 sorghum varieties were investigated using a germinator method (pneumatic procedure) and for six sorghums using a jar method (floor procedure) (Beta et al., 1995). Density of caryopses decreased for all sorghums after malting. Dry matter losses ranged from 8 to 19% and α-amylase activity ranged from 25 to 183 U/g, with two varieties having activity levels similar to that of barley malt. Reduction in pasting viscosity and sorghum diastatic power (SDU) was significantly correlated with α-amylase activity. β-amylase activity was low ranging from 11 to 41 U/g. The jar malting method yielded malts with lower dry matter losses and low levels of α-amylase and β-amylase activity, except for one cultivar compared to the pneumatic malting procedure. There is need control and optimise malting conditions to obtain high level of enzyme activity.

Beta et al. (2000a) investigated the effects of chemical treatments on polyphenols and malt quality in sorghum varieties of Zimbabwe. Tannin-containing sorghums, *Chirimaugute* and DC-75, and a tannin-free sorghum, SV2, were steeped in water, HCl (0.25 M), formaldehyde (0.017 M) and NaOH (0.075 M) for 8 and 24 h. germination was carried out for 2 and 5 days. Steeping in NaOH enhanced water uptake of the grains compared with the other treatments. All treatments reduced the polyphenol content of the raw grain and treatment with NaOH or formaldehyde was more effective than water or HCl. Malting alone was not an effective method of reducing the enzyme inhibitory power of the sorghum tannins. Malt quality as determined by diastatic power was higher in DC-75 malt than in *Chirimaugute* and SV-2 malt. Available diastatic power was markedly improved by the NaOH and formaldehyde treatments of the tannin-containing varieties. It was concluded that the steeping in dilute NaOH was effective in detoxifying high-tannin sorghums, reducing the steeping period and enhancing malt quality.

Suitable methods are required for milling tannin-containing sorghums. Conditioning sorghum using the same moisture levels applied to wheat results in a less clean fractionation, as the sorghum bran is much more brittle. Milling high tannin sorghums is particularly challenging, as antinutritional tannins contained in the testa layer have to be removed or the tannins extracted or transformed. Tannin-containing sorghums tend to be soft and thus recovery of high endosperm is difficult. The effect of chemical conditioning on the milling of high-tannin sorghum was investigated by Beta et al. (2000b). Sorghum varieties SV-2 (tannin-free), Chirimaugute (medium-tannin), and DC-75 (high-tannin) were milled using a simple roller mill and a multi-sample tangential decortication device. Grain was conditioned up to 20% moisture prior to milling using HCl (0.9%, v/v), formaldehyde (HCHO; 0.05%, v/v), NaOH (0.3%, w/v) and water as control. Abrasive decortication and roller milling reduced levels of the polyphenols, but this reduction was affected by variety, chemical treatment and conditioning moisture. NaOH and HCHO treatments gave lower polyphenol content in the meal and offal after roller milling. Enzyme inhibition by polyphenols was reduced by 52% after decortication or roller milling. Chemical treatment did not significantly affect enzyme inhibition levels after decortication. NaOH and HCHO treatments gave lowest enzyme inhibition when *Chiri-maugute* was roller milled at 20% moisture. The yield of product obtained after decortication was high at 12% moisture for SV-2 and *Chirimaugute* and at 16% conditioning moisture for DC-75. Conditioning to 20% moisture prior to milling did not improve product yield.

Roller milling and decortication resulted in products that were lighter in colour than the grain. Abrasive décortication and roller milling plus NaOH and HCHO treatments reduced tannin content of offal. It was concluded that conditioning using NaOH could be advantageous in roller milling but not in decortication of tannin-containing sorghums.

Starch is the major chemical component of cereal grains including sorghum and there has been increased interest in sorghum starch extraction. Normal sorghum starches are typically type B, moderate swelling starches as classified by Schoch and Maywald (1968). Sorghum starch is technologically equivalent to maize starch, however bleaching to remove polyphenolic pigments not present in maize add to the processing cost. It is established that traditional local landrace varieties of sorghum are grown in semi-arid areas of Zimbabwe, and that these grains play a significant role in the local economy. However, little is known about the starch properties of local landrace varieties of sorghum grown in Zimbabwe and the environmental effects of these. Beta and Corke (2001a) determined environmental and genetic variation in sorghum starch properties among eight local landrace varieties, one improved cultivar (SV-2) and one hybrid (DC-75) that are widely grown in Zimbabwe. Amylose content, pasting (peak (PV), hot paste (HPV), cool-paste (CPV) viscosity), textural and thermal (gelatinisation peak temperature (Tp) and gelatinisation energy ΔH)) properties of the starch isolated from the cultivars were determined. The F-tests from analyses of variance detected significant ($\rho < 0.001$) differences among genotypes and growing environments for the starch properties measured. The results indicated that a range of genetic and environmental variability exists for these traits in sorghum genotypes although the latter could be greater than varietal effects. Hybrid DC-75 largely differed in starch amylose content, pasting PV, and gel hardness from the local landrace varieties. Environments used for local landrace varieties caused significant differences in starch properties, hence selection and monitoring of growing conditions is essential if a particular genotype is to maintain minimum variation in the desired pasting, textural or thermal properties.

Beta et al. (2000c) determined the relationship between sorghum grain polyphenol content, grain structure, and starch properties by extracting starch from 10 sorghum varieties using an alkali steep and wet milling procedure. SV-2, a tannin-free variety with white pericarp, gave a white starch. Varieties having red or white pericarp and higher polyphenol levels gave pink starches. Hunter colour values (l, a, b) of the starches were not correlated with grain polyphenol content. Grain appearance in terms of pericarp colour, or presence or absence of pigmented testa, did not relate to the intense pink colouration of sorghum starches. Starch amylase content was significantly negatively correlated to grain floury endosperm texture. Sorghum starches had higher peak viscosity in pasting than commercial maize starch; time taken to reach peak viscosity from the initial viscosity rise was less for sorghum starches than maize starch. However, sorghum starches had a higher rate of shear thinning than maize starch. There was a significant positive correlation between grain polyphenol content and starch peak viscosity. Starch gel hardness was negatively correlated to pasting properties of shear thinning and paste breakdown. It was concluded that sorghum grain polyphenol content and grain characteristics influence its starch properties.

The noodle quality as related to sorghum starch physiccochemical properties (amylose content and pasting, textural, and thermal properties) was determined by Beta and Corke (2001b) in 10 sorghum varieties. The amylose content was 24 - 30%. DC-75 starch had the highest peak viscosity. Gelatinisation peak temperature occurred over a narrow range (67 - 69°C). The starch noodles prepared either white or pink depending whether white or red varieties were used. Cooking enhanced the pink coloration of noodles. Cooking loss was low, noodle elasticity highly correlated with starch pasting properties of hot paste viscosity and cold paste viscosity. Noodle rehydration was significantly correlated to the initial swelling temperature of starch and gelatinisation peak temperature. The results suggested a potential area of application for sorghum genotypes of different grain colours and evaluation of starch properties could be a good starting point for selecting sorghum genotypes with superior noodle-making properties.

Aflatoxin as a mycotoxin constitutes a real human threat. Aflatoxins are found in foodstuffs such as cereals and groundnuts and are not destroyed by normal industrial processing or cooking since they are heat-stable. They are produced by *Aspergillus, Penicilium* and *Fusarium* species especially aflatoxin B1 (AFB1). AFB1 is transformed through hydroxylation into aflatoxin M1 (AFM1) which is found in human breast milk. Research on population exposures to aflatoxins was carried out in Zimbabwe. Lamplugh and Hendrickse (1986) investigated the role of aflatoxins in kwashiorkor in children and hepatocarcinoma in Zimbabwe and found out that aflatoxins levels were higher from marasmic kwashiorkor than from normally nourished children. Wild et al. (1987) concluded that children in Zimbabwe were exposed to aflatoxins in their diets. Nyathi et al., (1987, 1989) reported the detection of aflatoxins in human urine and breast milk in Zimbabwe in samples from across the country. The most predominant aflatoxins found were AFM1 and AFG. The national average of urine samples contaminated was 6.0 percent. There were, however, some areas in which the extent of contamination was 34%. Of the 54 breast milk samples collected, 11% were contaminated mainly with AFM. There remain need to constantly monitor the presence of aflatoxin in cereals and groundnuts and their products in Zimbabwe. There is also need to carry out research on the exposure of the Zimbabwean population to other mycotoxins such as ochratoxins, zearalenone and fumonisins.

Fruits and vegetables

Fruits and vegetables play a major and increasing role in basic human nutrition, food security and agricultural diversification. Fruits and vegetables are important sources of vitamins and minerals; they also contribute to roughage and fibre, and supplementary protein and calories. They play direct and indirect roles in diversifying dietary patterns and providing employment and income to purchase the components of a balanced diet. Nevertheless, during the last decades, and despite their economic role and their importance in human diet, they have not generally been given the research attention they deserve from food and nutritionist scientists in Zimbabwe and in Africa in general. Scientific publications on detailed nutritional value and post harvest losses of fruits and vegetables of Zimbabwe are scarce. Research on fruits and vegetables is more reported two types of sources: (1) Cultural investigations: publications by anthropologists, geographers, historians, and sociologists sometimes contain food pattern data on use of edible wild plants (Grivetti and Ogle, 2000; Richards, 1939; Zinyama et al., 1990); (2) description and inventory: botanical inventories of locally available species, sometimes contain food and medicinal data (Campbell, 1987. These research by social scientists, anthropologists, economists, and geographers are conducted in professional isolation, and but these few studies contain quantifiable data that document dietary intake, proximate analysis and micronutrient content.

In an effort to improve the knowledge on the nutritive composition and contribution of local fruits and vegetables to household food security, nutrition and health in Zimbabwe, the Departments of Biochemistry, Food, Nutrition and Family Sciences, University of Zimbabwe have embarked on a project to promote wild plant foods by documenting the wild plant foods, their preparation and nutritional content. There are now a number of publications from this project and are summarised below.

A study was conducted to identify soluble sugars, organic acids and phenolic compounds of *Ziziphus mauritiana* fruit (Muchuweti et al., 2005a). *Z. mauritiana* fruit is commonly consumed as fresh or dehydrated; the powder from the fruit is used for baking, and to prepare jam. The sugars identified to be present in the fruits of *Z. mauritiana* were galactose, fructose and glucose. The phenolic compounds identified were caffeic acid, ρ-coumaric acid, ρ-hydroxybenzoic acid, ferulic acid. The organic acids identified were citric acid, malonic acid and malic acid. Sugars are responsible for the sweet taste of many fruits, organic acids are responsible for the sour taste of fresh fruit and phenolic compounds are non-nutritive but have been associated with therapeutic effect such as anti-bacterial, anti-thromboitic and anti-allergic, and anti-mutagenic. Many of these effects are from the potent antioxidant and free-radical scavenging properties of phenolic compounds (Ndlala et al., 2006; 2008).

Uapaka kirkiana fruits (*mazhanje* or *umhobhohobho*) are among the most popular fruits in Zimbabwe and are eaten fresh or processed into a variety of products including juices, squash, wines, sweet beer, porridge, jams and cakes. The phenolic compounds from *U. kirkiana* unripe pulp, seed coat, peel and embryo, as well as from ripe pulp, seed coat, embryo and peel portions of the fruit were analysed by Muchuweti et al. (2006). More tannins, flavonoids and gallotannins were detected in the embryos of both ripe and raw fruit and the least amounts were found in both ripe and raw seed coats. Raw fruits showed high concentrations of tannins compared to the ripe fruits. The phenolic acids (ρ-hydroxybenzoic acid) were similar in the peel and pulp. The degree of polymer-risation of condensed tannins of *U. kirkiana and Z. mauritiana* fruits were estimated to be between 4 and 10 monomer units of catechin per polymer of tannins in the different portions of the two fruits when using the modified vanillin-HCl method (Muchuweti et al., 2005b).

Phenolic composition of *Flacourtia indica* (Batoka plum), *Opuntia megacanthia* (L.) Mill and *Sclerocarya birrea* from Zimbabwe were investigated by Ndlala et al. (2007a) using traditional colorimetric as well as HPLC methods. The total phenolics, flavanoids and condensed tannin levels varied with species. *S. birrea* pulp had the highest total phenolics (2262 µg GAE/g), flavanoids (202 µg GAE/g) and condensed tannins (6%). *F. indica* pulp contained the least total phenolics (334 µg GAE/g), flavanoids (41 µg GAE/g) and condensed tannins (1.4%). There were no significant differences in the total phenolics between the peels and pulp of the fruits. However, significant difference was observed in the flavanoids and the condensed tannins between the peels and pulps of the fruits assayed. Ferulic acid, caffeic acid and vanillic acid wee the dominant phenolic acids in the three fruits.

Ndlala et al. (2007b) also studied the phenolic content and profiles of selected wild fruits of Zimbabwe: *Ximenia caffra*, *Artobotrys brachypetalus* (*mukusvo* in shona) and *Syzygium cordatum* (*hute* in shona) using colorimetric and HPLC (high-performance liquid chromatography) methods. *X. caffra* fruit peels contained the highest amounts of total phenolics amounting to 1205 µg g^{-1} in fresh weight, flavanols amounting to 27 µg g^{-1} and phenolic acids HPLC profile compared with the other fruits. *S. cordatum* fruit peels contained the least amounts of phenolics amounting to 20 µg g^{-1}, flavanols of 0.8 µg g^{-1} and phenolic acids' HPLC profiles showed low concentrations. More total phenolics were detected in peels than in pulps in all the fruit extracts. Vanillic acid was the common free phenolic acid detected by HPLC, occurring in all portions of the three fruits. A comparative antioxidant potentials and degrees of polymerisation of six wild fruits (*X. caffra* (sour plum), *S. birrea* (marula), *Parinari curatellifolia* (mobola plum), *Vitex payos* (chocolate berry), *Bridelia molis* (velvet sweet-berry) and *Berchemia zeyheri* (red ivory) were carried out by Ndlala et al. (2006). Aqueous methanolic extracts from the six fruits were assayed for scavenging effect on 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical, reducing power, superoxide anion radical scavenging effect and the inhibition of phospholipids peroxidation using colorimetric method. The peels and pulps of sour plum exhibited highest activity compared to the peels and pulps of the other fruits. Sour plum showed high reducing capacities both in the peel and pulp compared to the other fruits. A high concentrations of extract over 75% superoxide anion scavenging effect was observed for velvet sweet-berry whilst at concentrations of 40 and 60 mg sample equivalent/µl red ivory showed a high anion scavenging capacity. Velvet sweet-berry, sour plum peel and pulp and chocolate berry peel showed high capacities to inhibit lipid peroxidation at high concentrations. The degrees of polymerisation varied between 7 to 16 monomer units of catechin per polymer of phenolic compounds in the different portions of the six fruits.

Ndlala et al. (2008) also investigated the antioxidant properties of methanolic extracts from *Diospyros mespiliformis* (jackal berry), *F. indica* (Batoka plum), *Uapaca kirkiana* (wild loquat) and *Z. mauritania* (yellow berry) fruits. Methanol extracts from the four wild fruits were analysed for radical-scavenging effect of DPPH radical, reducing power and anion radical effect on superoxide anion using colorimetric method. There was an increase in the radical-scavenging effect, reducing power and superoxide anion radical-scavenging effect as the concentration of sample was increased. *Diospyros mespiliformis* had high DPPH radical-scavenging capacity. The peels of *F. indica* and *U. kirkiana* had higher DPPH radical-scavenging effects, reducing power and superoxide-scavenging effects compared with the pulp while the pulp of *Z. mauritania* had high DPPH radical-scavenging effects reducing power and superoxide-scavenging effects compared with the peel. It was concluded that these four fruits are potentially new valuable ingredients for food and nutriceutical applica-tions in the promotion of health.

The antioxidant properties of the fruits of Zimbabwe need further studies. While many naturally occurring simple phenolics scavenge radicals as effectively as vitamins A and E when tested in vitro, there is a paucity of studies on the bioavailability of the simple and complex phenolics and their stability. Their antioxidant properties need to be balanced with their effect on binding proteins, carbohydrates and minerals which affect the nutritional and functional value of the bound constituents. There is need to quantify the levels required for beneficial antioxidant effect to be reached and the antinutritional properties. There is also a dearth of data on the chemical forms of phenolic compounds identified so far in the fruits of Zimbabwe and also their nature upon processing. There is need to identify the phenolics reported in the fruits and sorghum varieties by using modern method of analyses, e.g., fractionation of the phenolic compounds using a combination of liquid chromatography with Sephadex LH-20 and RP-HPLC would useful for studies on structure-function relation-ships among sorghum and fruit phenolics.

It has been estimated that half of the world's fruits and vegetables are lost as a result of postharvest browning reactions involving polyphenol oxidase (PPO). Fruit and vegetables tissues are injured during handling, packaging or processing causing discolouration to occur which results in loss of appeal to consumers and market value of the products. This unfavourable enzymatic browning occurs in many fruits and vegetables. Muchuweti et al. (2006) investigated the characteristics of polyphenol oxidase extracted from *U. kirkiana* fruits. PPO was extracted and purified from *U. kirkiana* peel and pulp by ammonium sulphate precipitation and dialysis and purified further by gel filtration chromatography. The optimum pH was 7 and 8 for peel and pulp PPO, respectively. The optimum temperature for peel and pulp PPO was 45 and 35°C, respectively. The most effective inhibitors of PPO enzyme were sodium azide, and citric acid for both peel and pulp PPO. V_{max} and K_m values were 13.6 units min^{-1} and 4.9 mmol l^{-1}, respect-tively for peel; and 14.03 units min^{-1} and 5.4 mmol l^{-1}, respectively for pulp PPO. Three isozymes of *U. kirkiana* PPO were detected by polyacrylamide gel electrophoresis, and one of the isozyme had a molecular weight of 26 625 Da. The characterisation of PPO is of importance in the development of means of overcoming the post-harvest browning reactions that occur in fruits and vegetables. There is need to follow the PPO profile of the *U. kirkiana* fruits as they ripen and are harvested, and when they are transported and marketed.

U. kirkiana is a tree fruit species that grows in the miombo woodlands of southern Africa. Rapid perishability has been identified as one of the major constraints limiting household utilisation and marketing of the fruit. Fruit darkening is one of the major concerns for *U. kirkiana* fruit as indicated by fruit gatherers and marketers in Zimbabwe and Malawi (Kadzere et al., 2004). The cause of post-harvest damage and darkening profile in fresh fruit of *U. kirkiana* was investigated by Kadzere et al. (2006). Unwashed and washed ripe fruits were also exposed to direct sunlight to mimic the conditions at roadside where the fruit are commonly sold and then compared with fruit kept under shade. Incising green fruit accelerated skin darkening and loss of yellowness and greenness as indicated by decreases in chroma *L** and *b** values, and increasing *a** values, respectively. Decreases in skin brightness and yellow-ness also occurred in the incised brown skinned ripe fruit. Severity of darkening increased with increasing level of damage on the skin. Peeling and slicing of both green and brown skinned fruit resulted in loss of flesh brightness, and yellowness and greenness over time. Exposing the ripe fruit to direct sunlight after harvest resulted in more skin darkening compared with keeping the fruit under shade. No significant differences in darkening were found between unwashed and washed fruit. The study demonstrated the important contribution of exposure fruits to direct sunlight towards post-harvest fruit darkening.

Polygalacturonase (PG) is an enzyme that is produced by several fruits (tomatoes, peaches, avocado and pears), which soften on ripening. PG has been found to play a leading role in fruit ripening. The PG from four Zimbabwean edible wild fruits *Z. mauritiana*, *U. kirkiana, Tamarindus indica* and *Berchemia discolour* were extracted and characterised by Muchuweti et al. (2005c). The proteins concentrations in the enzyme extracts ranged from 0.82 to 1.97 mg/ml and enzyme activities ranged from 1.99 to 6.64 mmol min^{-1} mg^{-1} in the four fruits extracts. Optimum pH of the enzyme ranged from 4.5 to 5 and optimum temperature from 25 to 37°C. The K_m and V_{max} ranged from 0.12 - 0.25 mg/ml and 0.006 to 0.012 mmol reducing groups/min/mg protein, respect-ively in the four enzyme extracts. Ripe *U. kirkiana* fruit which had the highest PG activity is a potential source of PG for industrial applications. Characterisation of the PG is necessary for its industrial applications.

Caramel colours, the most widely used food colours, are brown powders or viscous liquids that are used to impart yellow to dark brown hues to carbonated beverages, distilled liquers, pharmaceutical flavouring extracts, candies, soups and bakery products (Chappel and Howell, 1992). Benhura et al. (1999) investigated the facile formation of caramel colours using the polysaccharide material that was extracted from the fruit of *Azanza garckeana*. *A. garckeana* is small tree that grows in central and southern Africa. In Zimbabwe, the tree is found growing in large numbers in low rainfall areas, and bears fruit the size of a peach, which turns from green to dark brown upon ripening. The mucilage from *A. garckeana* fruit was extracted with water and the extract heated at 130°C in the presence of ammonium salts. Upon heating the mucilage, composed of galactose, glucose, arabinose and rhamnose units, a brown colour was formed. When water was not allowed to evaporate off, the extent of the colour formation depended on the initial concentration of the mucilage. The amount of soluble colour that was formed decreased as the viscous mass was transformed into a friable insoluble mass. The presence of ammonium salts had only a small effect on the development of colour. The facile formation of a caramel colour by the extract of *A. garckeana* provides an opportunity to the material as a renewable resource in the production of a product that can be used by modern technology.

Plant hydrocolloids, long chain high molecular weight polymers that dissolve or disperse in water to give a thickening, stabilising or gelling effect, are generally polyuronides composed of more than one type of monosaccharides unit (Benhura and Chidewe, 2002). The polymers are used to improve or manipulate the texture of food products because of their ability to retard flow, modify gelling characteristics, and preserve emulsions and suspensions. Most hydrocolloids used in industry are plant origin. Benhura and Chidewe (2002) investigated some properties of a polysaccharide preparation that is isolated from *Cordia abyssinica*, fruit tree commonly found in Zimbabwe at low altitude, in warm, moist riverine bushvelds. An acidic polysaccharide gum was isolated from the fruit of *C. abyssinica* by extraction with alkali and precipitation with acid. The polysaccharide preparation had a specific optical rotation of -50°, moisture content of 9.1%, ash content of 0.7% and uronic acid content of 8.7%. In the acid hydrolysates of *C. abyssinica* polysaccharide, galactose was identified by HPLC to be the main monosaccharide released (27%), followed by rhamnose (21%) and mannose (17%). Xylose (11%), glucose (10%), arabinose (9.5%) and uronic acids (5%) were also identified as components of the polymer. It also has a protein fraction of 2.6% which would be expected to contribute to the emulsifying properties of the polysaccharide. The identified properties of the polysaccharide of *C. abyssinica* contribute towards the understanding of the origin of adhesiveness in polysaccharides. An understanding of the structure and functional properties of the gum would be necessary in order to effectively exploit the gum.

The viscosity and solubility properties of the polysaccharide that is isolated from the fruit of *Cordia abyssinica*, was investigated by Benhura and Katayi-Chidewe (2000). The polysaccharides from the fruit of *C. abyssinica* were extracted at pH 8.9 and precipitated in acid. The acidic precipitate was dissolved in solutions of $NaHCO_3$, Na_2CO_3, KOH, NaOH and NH_4OH. The viscosity of the polysaccharide solutions and the time taken to bring about dissolution depended on the nature of alkali used. The polymer, routinely dissolved in Na_2CO_3 (0.1 M) was insoluble below pH 7. Viscosity increased with increasing pH to a maximum of viscosity being observed at pH 9. The viscosity of the polymer increased with polysaccharide concentration. Increasing the temperature of the polysaccharide solution resulted in nearly linear decrease in viscosity.

Emulsions are intimate mixtures of two immiscible liquids in which one phase is dispersed throughout the other as small discrete droplets whose mean diameter vary from < 2 to > 100 µm. Food emulsions are used as vehicles for adding flavour to food, diluting ingredients and hiding objectionable odours or tastes. The emulsifying properties of the polysaccharide isolated from the fruit of *C. abyssinica* was determined by Benhura and Katayi-Chidewe, (2004). Emulsions of vegetable oil containing up to 1% of the polysaccharide in phosphate pH 7.4 buffer, were prepared using a hand piston hogenizer. Emulsification was assessed by diluting samples of the emulsions in sodium dodecyl sulphate and measuring absorbance at 500 nm. Addition of increasing concentrations of the polysaccharide up to 1% enhanced emulsification and emulsion stability. Above 1% concentration the polysaccharide solutions were too viscous for making emulsions conveniently. At a constant concentration of the polysaccharide, addition of up to a 1% concentration salt enhanced emulsion formation. Further addition of salt above 1% resulted in no further changes in emulsifying ability, but the stability of the emulsions formed decreased on increasing the concentration of salt above 1%. The polysaccharide had poor emulsifying ability below pH 7 and emulsifying ability increased with pH between 7 and 11. The polysaccharide from *Co. abyssinica* might have potential applications in food, textile, pharmaceutical and other industries.

There have been a lot of research efforts to understand and find applications for the mucilage that is isolated from ruredzo (*Dicerocaryum zanguebarium*), found in Zimbabwe (Benhura and Mavhudzi, 1996). Gums and mucilages are polysaccharides that dissolve in water to form colloidal dispersions and are used commercially in their natural or modified state. In various industries, gums and mucilages are used for stabilisation of emulsions, suspension of particulates, control of crystallisation, inhibition of syneresis, encapsulation, formation of films and thickening. Ruredzo is a creeping plant that grows widely in sandy soils of Southern Africa and is traditionally used as food and medicine for treating measles and facilitating birth in domestic animals and humans. This plant appears to be a suitable candidate for the commercial exploitation of its mucilage, after the mucilage has been properly characterised. The mucilage from ruredzo is a pectic material with molecular weight of about 500 000 dalton and has been shown to contain 8% uronic acids. The polysaccharide, after reduction of carboxyl groups, was shown to consist of galactose, xylose, arabinose and mannose in the ratio 21:19:12:1 (Benhura and Marume, 1993a).

Emulsifying properties of mucilage from ruredzo were studied under various conditions of concentration of mucilage, concentration of salt, and pH by Benhura and Marume (1993b). Emulsification was assessed by diluteing samples of emulsions in sodium dodecyl sulphate and measuring absorbance. Emulsification capacity increased with mucilage concentration but was decreased in the presence of NaCl and $CaCl_2$. The optimum pH for the formation of emulsions was about 7.4 with poor emulsification at both higher and lower pHs. The emulsifying property is an important function of gums and mucilage in the food industry where they are used for stabilisation of emulsions, suspension of particulates, control of crystallisation, encapsulation, formation of films and thickening. Crosslinked mucilage prepared from ruredzo was used in the purification of polygalacturonase extracted from ripe tomatoes (Benhura and Mavhudzi, 1996). Used crosslinked mucilage could be regenerated and effectively used for the purification procedure. Some properties of the ruredzo mucilage crosslinked with epichlorohydrin were reported by Benhura and Mavhudzi-Nyambayo (1997). The depolymerisation properties of mucilage from ruredzo by ascorbic acid in the presence of catalysts were reported by Benhura and Mavhudzi-Nyambayo (1999). No change was observed in the viscosity of samples from ruredzo when treated with 5 mM ascorbic acid. When treated with ascorbic acid in the presence of copper and iron, the amount of reducing sugars increased. The viscosity behaviour of the mucilage extra-cted from ruredzo was investigated by Benhura and Marume, (2006) after cations from the mucilage were removed by Dowex 50W-X12 resin. Addition of $CaCl_2$, NaCl and sucrose decreased the viscosity of the decationised mucilage studied.

Z. mauritiana (Ber) is an important wild fruit in sub-Saharan Africa contributing to food security and household income. The fruit is locally called *masau*, and is eaten raw or the pulp is processed into products such as porridge, traditional cakes, mahewu and jam or fermented into beverages through natural fermentation. There has been some research to improve the ripening and keeping quality of the fruits and to isolate the micro-organisms from the *masau* for possible use as starter cultures for the fermentation of the beverages. In Zimbabwe, the *Z. mauritiana* fruit trees are found in the Zambezi valley, where the fruit is harvested at different stages of ripening. The organoleptic properties of the fruits depend on the post-harvest drying method and ripening stage at harvest. Tembo et al. (2008a) carried out a study to evaluate the effect of different stages of ripening on the colour and quality of Z. *mauritiana* fruits during drying. They used green, yellowish-brown and brown fruit categories and blanched some of them before drying under the solar dryer and the open sun drying methods. The green fruits lost weight more significantly during drying than the yellowish-brown and brown fruits regardless of the drying method. The brown and fully ripened fruits developed darker brown colour than the green and yellowish fruits. The solar dryer was more effective than the sun method in reducing fruit moisture content during drying. Tembo et al. (2008b) further investigated the effect of pre-drying treatment, drying method and the subsequent duration of storage on the quality attributes of Z. *mauritiana* fruits harvested from Zambezi valley. The vitamin C content was reduced more significantly in solar dried fruits than in sun dried fruits. The purity (chroma) and lightness (value) of fruit colour decreased with increasing duration of drying irrespective of the drying method. Blanching fruits before drying reduced the colour chroma and vitamin C content significantly compared to non-blanched fruits. Different storage temperatures and durations were evaluated to determine the appropriate storage conditions of Z. *mauritiana* fresh fruits (Tembo et al., 2008c). Fruits stored at 5°C lost only 48% of their weight during 12 weeks storage period while the fruits stored at 15 and 22°C lost 70 and 75% of weight, respectively. Vitamin C loss, reducing sugar and titratable acidity reduction were less at the low temperature storage conditions. They concluded that fruits stored at low storage temperature gave better fruit colour, lost the least weight and maintained the best appearance than those stored at intermediate and ambient temperatures. Yeasts, yeast-like fungi, and lactic acid bacteria present on the unripe, ripe and dried fruits, and in the fermented *masau* fruits collected from Muzarabani district in Zimbabwe were isolated and identified using physiological and molecular methods by Nyanga et al. (2007). *Aureobasidium pullulans* was the dominant species on the unripe fruits but was not isolated in the fermented fruit pulp. *S. cerevisiae, Issatchenkia orientalis, Pichia fabianii* and *S. fibuligera* were predominant in the fermented fruit pulp but were not detected in unripe fruits. *S. cerevisiae, I. orientalis, P. fabianii* and *S. fibuligera* are fermentative yeasts and these might e used in the future development of starter cultures to produce better quality fermented products from *masau* fruits. The predominant lactic acid bacteria were *Lactobacillus agilis* and *L. plantarum* and these could be used in mixed starter cultures with yeasts.

Vegetables are an important part of the Zimbabwean diet. Indigenous vegetables (IVs) have a strategic food security role, offering significant opportunities for the poor, particularly women, through farming, processing and trading activities. Until recently, these commodities were viewed as minor crops of little economic importance, and therefore had not been a focus for research in Africa. Little is known of their productive potential, economic value and contribution to household nutrition and livelihoods, and in relation to extracted products for nutritional and medicinal use. In addition, IVs are a resource that is being subject to habitat and genetic erosion, with loss of local knowledge. There are approximately 25 different species of African vegetables in Zimbabwe of which about 10 are frequently cultivated while others occur naturally. These crops have undergone some selective pressure, but have not benefited from research, so there are no uniform varieties. This is a major concern for both farmers and traders. They do not require large capital investment and production systems are short and labour intensive. And because they are affordable, vegetables are also an important source of nutrition for poor urban families. In recent years there has been formal research by national agricultural research programmes and international agricultural organisations on cultivation methods to improve yield (Chigumira, 1997; Mushita, 1997). Surveys carried out in Harare, Bulawayo and Mutare by the Horticulture Research Centre confirmed the increasing role of indigenous vegetables in food security and income generation. A series of surveys revealed that indigenous vegetables provide a source of leafy vegetables from August to

December - a period of scarcity. However, demand is outstripping supply. It also found that trade of indigenous vegetables has spread to higher income groups and retail outlets, including supermarkets. The surveys highlighted constraints in cultivation and trading, related to lack of seed, low productivity, high perishability and poor quality of processed products (mostly dried leaves). Most producers undertake some processing and storage - a task usually done by women - and surveys have revealed that there is an increasing demand for dried and ground vegetables in urban centres. The most common processing method is blanching in boiling water and then sun and/or air-drying. However, the quality of the dried products, particularly of leafy vegetables, is compromised by poor drying conditions, poor hygiene and inadequate storage conditions, and the end product is vulnerable to insect and fungal attack. However, there is little published research on the nutritional composition of Zimbabwean vegetables and the information available even in nutritive value publication by Chitsiku is by inference to research done on similar vegetables in other African countries. There is therefore an impetus to carry out research on the nutritional composition of Zimbabwean vegetables by Zimbabwean scientists.

Future research

An attempt was made to pinpoint significant research gaps throughout this review, and the applications of the research in critically reviewing the food science and technology research in Zimbabwe. Zimbabwe has an inventory of its indigenous and traditional foods and a food composition table; however, there is need to upgrade the inventory and food composition table. Zimbabwe is rich in traditional and indigenous foods and there are still quite a lot of the foods which has not been researched on to show their nutritional composition and value and methods of improving their processing and preservation are needed. Information is needed on the nutritional value of processed, cooked and home-prepared foods of Zimbabwe. We need to know their contribution in meeting energy, protein and macro- and micronutrient needs of the people. This information is also required to update the national food composition table.

Cassava (*Manihot esculenta*) is a major food crop in sub-Saharan Africa. It is primarily a root crop, but leaves and shoots, which are rich in proteins, are also often eaten. Its further value lies in its ability to grow in sub-optimal conditions, for example, drought and low soil fertility conditions, which often encountered in Zimbabwe. There is a great deal of effort of research in production of good planting material at the University of Zimbabwe and the Scientific, Research and Development Centre in Zimbabwe. However, most varieties of cassava need adequate processing to eliminate cyanide, which may lead to disorders of iodine deficiency and paralytic conditions in consumers. A dearth of knowledge about the processing of cassava into various food products and fears of cyanide poisoning, are factors restraining cultivation and consumption of cassava in Zimbabwe. Apart from subsistence, cassava may have industrial uses in brewing beer and in the production of ethanol and butanol for blending with petrol and diesel.

In Zimbabwe, the cost of animal sources of protein (mainly beef and chicken) is high and far beyond the reach of most of the low and middle-income families. There is need to explore and evaluate the nutritional value of potential alternative sources but less expensive sources of protein, such as edible insects and mushrooms.

The traditional use of insects as food continues to be widespread in tropical and subtropical countries and to provide significant nutritional, economic and ecological benefits for rural communities. In Zimbabwe research by Chavunduka (DeFoliart, 1999) concluded that insects are the cheapest source of animal protein for rural communities, that their consumption has averted many cases of malnutrition and that their use as a food should be encouraged. More than 40 species of insects representing at least 25 genera, 14 families and 7 orders have been reported as foods in Zimbabwe. These include the Coleoptra (beetles); Hymenoptera (ants); Lepidoptera (caterpillars) and Orthoptera (locusts), etc. Insects are rich in protein, vitamins and minerals, and a good source of iron and B-vitamins, besides adding variety to the diet. In good caterpillar areas, some fami-lies can make a fairly good living from selling caterpillars. Considering the economic, nutritional and ecological advantages of this traditional food source, its promotion deserves more attention both from national governments and assistance programmes. There is therefore, need for nutritional composition analysis of edible insects of Zimbabwe.

Forest foods such as mushrooms are widely consumed in most agricultural communities and even in many urban areas in Zimbabwe. In some cases, they provide a regular supplement to the diet; in others they represent a primary source of food. The per capita consumption of mushrooms during the rainy season in Zimbabwe can be as high as 1.8 kg. They are commonly valued as meat substitutes and they supply surprisingly large amounts of protein (up to 45 g per 100 g dry weight in some cases) and essential minerals. Scientists in the Departments of Biological Sciences and Crop Science, University of Zimbabwe and the Biotechnology Research Institute at the Scientific, Research and Development Centre are involved Oyster (*Pleurotus* spp.) mushroom and spawn production. There is no published literature in peer reviewed journals on the nutritional composition of the wild mushrooms of Zimbabwe.

Conclusion

Attention is repeatedly drawn to the use of locally produced raw materials in Southern Africa for food processing. The availability of abundant raw materials and the lack of the knowledge regarding their properties compounded with scarcity of suitable processing technologies at small-scale should serve as an impetus for food scientists to apply modern food processing technologies to local conditions. There have been significant research efforts to a better understanding of the nutritional qualities of local foods and their health implications in Zimbabwe. This paper has summarised most of the research and applications and shows that research in food science and technology in Zimbabwe has come of age. This paper also highlighted the country's strengths and weaknesses in food science research and development capacity. This work attempted to put together most of food biotechnological researches on Zimbabwean foods in peer reviewed scientific journals that have been done in Zimbabwe (or elsewhere by Zimbabweans together with their collaborators) over a period of 30 years for ease of reference and fostering of closer research collaborations. This review does not claim to be definitive or even exhaustive. The author is aware of the fact that results of research undertaken by some Zimbabwean researchers and students is still to be published or cannot be found in the scientific publications and international bibliographic databases.

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