African Journal of Biotechnology Vol. 7 (9), pp. 2509-2513, 2 May, 2008
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB07.907
ISSN 1684–5315 © 2008 Academic Journals

Full Length Research Paper

Ripening stage and drying method affecting colour and quality attributes of *Ziziphus mauritiana* fruits in Zimbabwe

Lovejoy Tembo[1,2], Z.A Chiteka[1], Irene Kadzere[2,3], Festus K Akinnifesi[4]* and F. Tagwira[1]

[1]Faculty of Agriculture and Natural Resources, Africa University, Box 1320, Mutare, Zimbabwe.
[2]Department of Agricultural Research and Extension Services, Agronomy Research Institute, Box CY 550, Causeway, Harare, Zimbabwe.
[3]World Agroforestry Centre (ICRAF), Southern Africa Regional Programme, Box Cy 594 Causeway Harare, Zimbabwe.
[4]World Agroforestry Centre (ICRAF), Southern Africa Regional Programme, Box 30798, Lilongwe, Malawi.

Accepted 7 March, 2008

***Ziziphus mauritiana Lamk.* (Ber) fruit is harvested at different stages of ripening in the Zambezi valley of Zimbabwe. We hypothesize that the organoleptic quality attributes of fruits depend on post-harvest drying method and ripening stage at harvest. This study was carried out to evaluate the effect of different stages of ripening on the quality of *Z. mauritiana* fruits during drying. The fruits were graded into green, yellowish-brown and brown categories and these formed the treatments. Some of these fruits were blanched before drying for 1, 2 and 3 weeks under the solar dryer and the open sun drying methods. The green fruits lost significantly (P<0.001) more weight during drying than the yellowish-brown and brown fruits regardless of the drying methods. The development of browning was more on the brown fruits than the green and yellowish-brown fruits.**

Key words: Ber, drying method, post harvest quality, blanching, fruit colour, harvesting stage.

INTRODUCTION

The increasing frequency of climatic risks, particularly El Niño related droughts, is exacting toll on smallholder farmers in Southern Africa, and these dry spells have led to serious food shortages in recent years (Kandji et al., 2006). Traditionally smallholder farmers minimize or cope with climatic risks by growing a variety of crops and opportunistic gathering of wild fruits for consumption and for sale (Akinnifesi et al., 2004, 2006; Mithöfer, 2005; Mithöfer and Waibel, 2003). In a survey carried out by Akinnifesi et al. (2004), it has been shown that as much as 80% of 323 households face food shortages from November to January. Furthermore, about 50% of the households in Malawi and 26% in Zambia resorted to gathering fruits as a strategy to cope with the severe famine in 2001. Mithöfer et al. (2006) also confirmed that availability of fruits increased the probability of households falling below poverty line by 30% during critical famine period.

Ziziphus mauritiana Lamk. (Ber) is widely consumed and traded fruit in southern Africa (Akinnifesi et al., 2006), and it has been among the top preferred indigenous fruits in Zimbabwe (Kadzere et al., 1998). *Z. mauritiana* is a drought-tolerant fruit tree that grows well in the Zambezi Valley area of Zimbabwe. Farmers in the Zambezi valley use various ripening indicators, based on their experience, to determine when to harvest the fruits. The time of year or season, fruit softening and abscission are some of the ripening indicators that are used by farmers to determine when to pick the fruits (Kadzere et al., 2004). These indicators have not been assessed and, therefore, their accuracy is not known.

*Corresponding author. E-mail: f.akinnifesi@africaonline.net, f.akinnifesi@cgiar.org.

Z. mauritiana is known to have a long flowering period, and hence fruit ripening occurs over a long period. The fruits have a high commercial value in Southern Africa, especially Zimbabwe (Saka, 1995) and are often harvested before maturity or natural ripening occurs, especially in areas where few *Z. mauritiana* fruit trees are found (Kwesiga and Mwanza, 1995), and during seasonal food shortage periods. Also, the harvesting methods used by farmers and rural dwellers rarely encourage selective harvesting of fruits that are at different stages of ripening. Such harvesting methods include: picking fruits from the ground following abscission, throwing stones and sticks into the trees, hitting stems with heavy stones and shaking the stems or branches to dislodge the fruits (Kadzere et al., 2004). It is likely that the organoleptic quality attributes of fruits will depend on post-harvest drying method and ripening stage at harvest. This study was undertaken to investigate the effect of ripening stage on the quality of the *Z. mauritiana* fruits during drying.

MATERIALS AND METHODS

Fruit collection site

This laboratory study was conducted from August to December 2006. The fresh fruits were collected in August from farmland in the Muzarabani district located at 240 km from Harare, Zimbabwe [400m a.s.l., 16°E and 31° S]. The area receives an annual rainfall ranging from 650 to 700 mm and mean annual temperatures of 32°C. The experiment was carried out at Harare Research Station, Department of Research and Extension (AREX). AREX is situated at an altitude of 1506 m a.s.l.; mean annual temperatures ranging from 10 to 26°C and an annual rainfall ranging between 800 and 1000 mm.

Fruit drying structures

Passive solar dryers (natural circulation or natural convection system) of the cabinet type were used in this study (Weisis and Buchinger, 2003). The solar dryer consisted of a large wooden cabinet with a slanting roof. The wooden cabinet was covered by a clear polythene sheet to create a green house effect. Trays consisting of a wooden frame and polythene were fitted in the cabinet to allow free air circulation. These were selected because they are simple to construct, require low labour costs and appropriate size for on-farm use. Below the trays, black plastic sheeting (collector) was installed to absorb heat which would be trapped inside the cabinet to create a green house effect. The circulation of the hot air dries the fruits. Each dryer measured 4.5 x 1.3 m was raised to 0.5 m above the ground and the tray was fitted at a height of one metre above the ground.

The low-cost open-sun traditional drying structure with the same dimensions as the solar dryer was constructed by erecting four poles on each corner and then firmly placing sticks across to make a flat surface where the fruits were dried.

Experimental design and treatments

The experiment was set up as a split-split-split plot design with three replicates. The drying methods were the main plots, blanching treatment the subplot, stage of harvest the sub-sub plot while the drying period was the sub-sub-sub plot.

Procedure

Freshly harvested fruits were first sorted to remove those damaged and the fruits were then graded into three categories based on their stage of ripening (level of greenness in the fruits). Three stages of ripening were identified as follows: green, yellowish-brown and brown fruits. Samples of fruits (approximately 200 fruits) in each category were weighed and allocated to each of the treatments.

Two blanching treatments (blanched and un-blanched), two drying methods (open sun and solar drying) and three sampling durations (one, two and three weeks) were randomly allocated to each sub sample. The fruits were weighed before blanching and soon after blanching, but before drying and also after drying. Each sample was spread on drying structures (50 cm by 65 cm) and the fruits were spread on a single layer.

The blanching process was done by placing the fruits at each sampling period in woven polythene bags and then submerging the bags in boiling water for four minutes. The blanching water was boiled in a big pot under an open fire. The temperature of the boiling water was 94ºC.

Fruit sampling and assessment

Fruit samples of two kilograms were collected from each of the three replicates at the beginning of the experiment before blanching and after blanching. The assumption was that all the fruits were uniform at the beginning of the experiment. The samples were used to determine the physical characteristics of the fruits (weight, colour, insect damage, firmness, size) and nutrient analysis. A sub-sample of 50 fruits was randomly picked from each of the three replicates and used to determine the physical characteristics of the fruits. Fruit colour was determined using the Munsell colour chart. The Munsell colour chart is based on the colour dimensions of hue, value and chroma. Chroma is the purity, intensity, saturation or richness of colour, value refers to the lightness or darkness of a colour and hue is the colour as perceived by the eye (Potter and Hotchkiss, 1998; Kadzere et al., 2006).

Insect damage was determined by assessing the presence of fruit damage on the fruit and opening the fruit to check the presence of insect larva inside each individual fruits. Fruit size was determined by measuring fruit length and diameter using callipers. Fruit diameter was measured at the widest part of the fruit while length was measured from the proximal to the distal ends of the fruits using outside veneer callipers for measuring outside diameter. An electronic balance was used to measure weight of the individual fruits to the nearest 0.01 g. Fruit quality was assessed for darkening during the drying process. Fruits that appeared black on the surface and in the flesh were recorded as undesirable. These could not be fitted on the Munsell colour chart values. A sub sample of 50 fruits was randomly picked from each replicate and used to determine the physical characteristics of the fruits.

Statistical analysis

Data were subjected to analysis of variance (ANOVA). The least significant difference (LSD) at P=0.05 was used for pair-wise comparison of means. Tests for normality using the Box Cox plot procedure showed that the data were not normally distributed. Square root transformations were carried out on proportions before they were subjected to ANOVA.

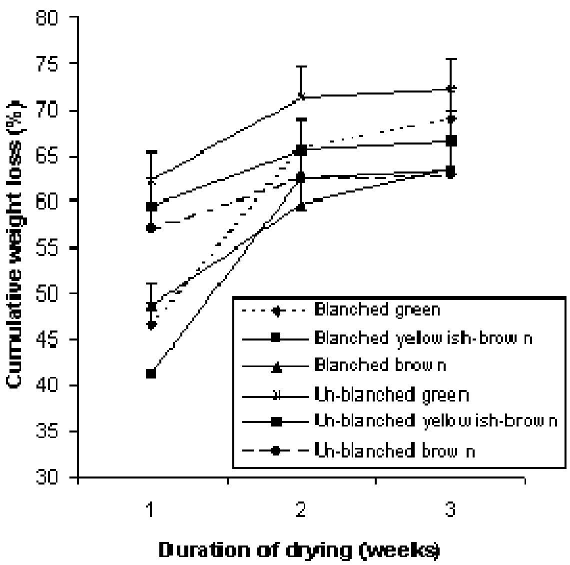

Figure 1. Effect of pre-drying treatments, duration of drying and stage of ripening on the cumulative weight loss (%) of *Z. mauritiana* fruit during drying. Vertical bars represent standard errors of means.

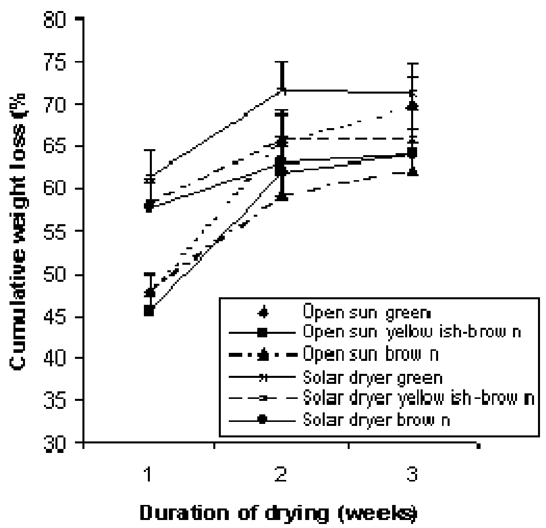

Figure 2. Effect of drying method, drying duration and stage of ripening on cumulative weight loss (%) of *Ziziphus mauritiana* fruits during drying. Vertical bars represent standard errors of means.

RESULTS

Cumulative weight loss during drying

The weight lost by the fruits during drying was dependent on the pre-drying treatment, drying method and duration, and ripening stage. The un-blanched fruits had significantly ($P<0.01$) higher weight loss than fruits that were blanched before drying (Figure 1). Drying unblanched fruits significantly increased ($P<0.05$) the weight loss for all stages of ripening. An increase in the duration of drying significantly increased the weight lost to week two. Beyond the second week, no significant increases in weight loss ($P>0.05$) were observed between the open sun and solar drying method (Figure 1).

Figure 2 showed the effect of drying method, drying duration and stage of ripening on cumulative weight loss (%) of fruits during drying. The solar dried fruits lost significantly ($P<0.05$) more weight regardless of the blanching treatment than the fruits dried under the open sun. The green fruits tended to lose more ($P<0.001$) weight than the yellowish brown and brown fruits regardless of the drying method (Figure 2). Drying fruits under the solar dryer significantly increased ($P<0.05$) weight loss across the ripening stages (Figure 2).

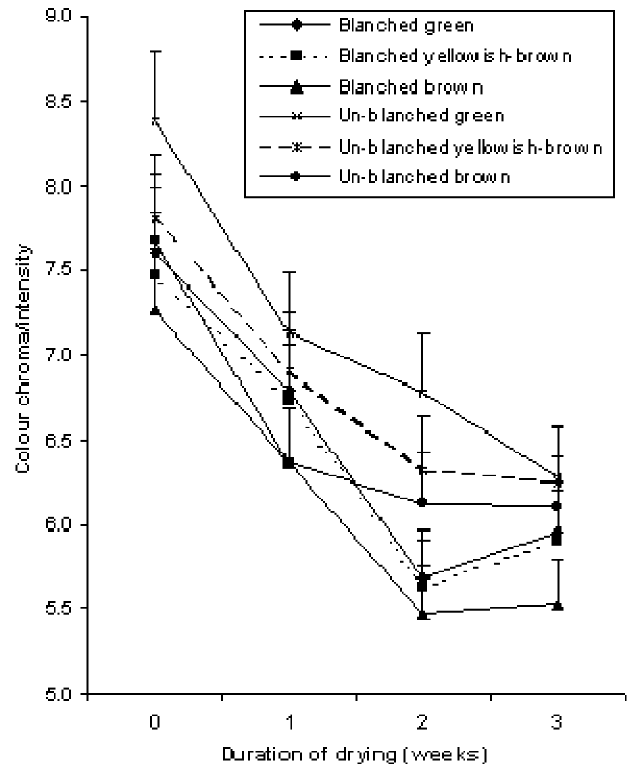

Figure 3a. Effect of blanching and ripening stage on *Ziziphus mauritiana* fruit colour chroma during drying. Vertical bars represent standard errors of means.

Colour attributes of fruits

The effect of drying method, pre-drying treatment and ripening stage on the colour chroma during drying is presented in Figure 3a. The blanched fruits exhibited significantly lower ($P<0.01$) intensity of colour than the unblanched fruits during drying. The green fruits main-

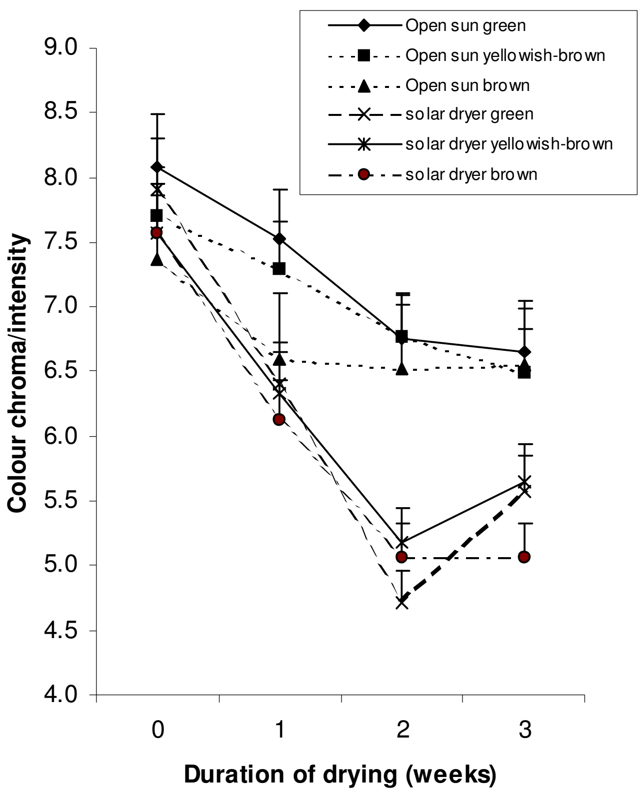

Figure 3b. Effect of drying method and ripening stage on *Ziziphus mauritiana* fruit colour chroma during drying. Vertical bars represent standard errors of means.

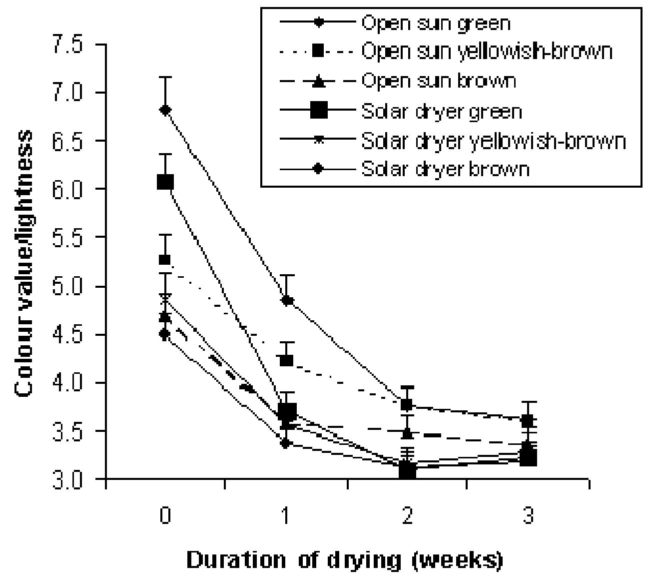

Figure 4. Effect of drying method, drying duration and ripening stage on *Ziziphus mauritiana* fruit colour value (lightness) during drying. Vertical bars represent standard errors of means.

tained high colour chroma during the drying process and the brown fruits had the least colour intensity among all the stages of ripening (Figure 3a). Development of browning tended to be more significant (P<0.05) on the brown fruits as evidenced by low colour intensity during the whole drying process. Fruits dried under the open sun maintained higher colour intensity than the fruits dried under the solar dryer (Figure 3b).

Figure 4 showed the effect of drying method, drying duration and ripening stage on the fruit colour value (lightness) during drying. Open sun drying maintained a significantly higher (P<0.01) value of colour (lightness) than the solar dried fruits during the whole drying process. The green fruits maintained a significantly high (P<0.001) colour intensity during drying. Generally, the fruits developed darkening as the duration of drying increased and this is evidenced by a decrease in colour lightness as the drying progressed (Figure 4).

DISCUSSION

Fruits dried in the solar dryer lost more weight than the fruits dried in the open sun structure. This is explained by the fact that temperatures in solar dryers are higher than the temperatures in the natural drying structure (Gallali et al., 2000) and therefore moisture removal was faster in the solar dryer. This makes the solar dryer a more effective method than the open sun structure in moisture removal.

The un-blanched fruits lost more weight than the blanched fruits during drying. The result showed that the blanching of *Z. mauritiana* fruits would delay the drying process. Fruits may have absorbed more water during blanching which took longer to remove. According to Lu, Fleming and McFeeters (2002), blanching can completely inactivate respiratory activities and consequently fruits lost less water during drying.

The greater loss of weight for green fruits of *Z. mauritiana* compared to yellowish-brown and brown fruits during drying in this study agrees with observations in other tropical fruits. In apple, citrus and avocado, immature fruits have been observed to have more stomata and lenticels and most guard cells lose their regulatory ability at harvest (Blanke, 1995). Therefore, the immature fruits lose moisture faster during drying through stomata and lenticels.

Blanching fruits before drying reduced the chroma of the fruits. According to Luo (1996), blanching reduces the content of vitamin C that is important for colour presservation during drying, and therefore the fruits may darken during drying. Rural farmers and marketers would benefit from drying un-blanched fruits, as these would improve the appearance of the fruits to the consumers.

Green fruits maintained higher colour chroma and value during drying (Figures 3a,b and 4). In fruits such as apples and mangoes, Vitamin C decreases as the fruit ripens (Lee and Kader 2000) and this could result in less development of darkening in immature fruits since Vitamin C is a preservative and acts as an antioxidant thereby keeping fruits from darkening during drying (Luo, 1996). Green fruits therefore would have higher content of vitamin C. Future work could verify the behaviour of *Z. mauritiana* fruits during drying with regard to vitamin C dynamics and the other organoleptic properties of the dried fruit.

Conclusion

The study provides evidence that the ripening stages of *Z. mauritiana* fruit influence post harvest attributes of dried fruits. The green fruits tended to dry faster as they lost more weight than the yellowish brown and brown fruits. The green fruits maintained higher colour intensity and lightness than the yellowish-brown and brown fruits. The brown and fully ripened fruits developed more darkening during drying than the yellowish brown fruits and the green fruits. However, there is need to investigate the nutrient content of the different categories of fruits and how the nutrients respond to drying.

ACKNOWLEDGEMENTS

The first author would like to thank the Regional Universities Forum (RUFORUM) for their partial support during this study. This work was carried out as part of the agroforestry activities of the World Agroforestry Centre (ICRAF) under the Protracted Relief Programme (PRP) in Zimbabwe with funding from the United Kingdom Department for International Development (UK-DFID). The support from the ICRAF staff in Harare, Mr. O. Chirimuzhengeni, Mr. C. Dube and Ms. M. Nyakuwa are appreciated. Thanks to Dr. K. Ramachela and the Agronomy Institute staff, Mr. L. Mundoza and Mr Maruseta for their assistance. The Government Analyst, Mr. Musiyambiri and his technical staff, and the Chemistry and Soil Research Institute for their assistance in the nutrient analysis of the fruits. Dr. B. Mvumi of the Department of Soil Science (UZ) and Mr. Nazare are thanked for their assistance in the construction of the solar dryers.

REFERENCES

Akinnifesi FK, Kwesiga F, Mhango J, Chilanga T, Mkonda A, Kadu CAC, Kadzere I, Mithofer D, Saka JDK, Sileshi G, Ramadhani T, Dhliwayo P (2006). Towards the development of miombo fruit trees as commercial tree crops in southern Africa. Forest. Tree. Livelihood. 16: 103-121.

Akinnifesi FK, Kwesiga F, Mhango J, Mkonda A, Chilanga T, Swai R (2004). Domesticating priority miombo indigenous fruit trees as a promising livelihood option for smallholder farmers in Southern Africa. Acta Hortic. 632: 15-30.

Blanke MM (1995). Regulation of respiration in apple, avocado and citrus orange fruit. Acta Hortic. 398: 139-146.

Gallali Yahya M, Abujnah Yahya K, Bannani Faiz K (2000). Preservation of fruits and vegetables using solar drier, a comparative study of natural and solar drying III; chemical analysis and sensory evaluation of the dried samples (grapes, figs, tomatoes and onions). Renewable Energy. 19: 203-212.

Kadzere I, Hove L, Gatsi T, Masarirambi MT, Tapfumaneyi L, Maforimbo E, Magumise I (2004). In: Rao MR, Kwesiga FR (eds) Current status of post-harvest handling and traditional processing of indigenous fruits in Zimbabwe. Proceedings of the Regional Agroforestry Conference on Agroforestry impacts on Livelihoods in Southern Africa: Putting Research into Practice. World Agroforestry Centre (ICRAF). Nairobi, Kenya. pp. 353-363.

Kadzere I, Chilanga TG, Ramadhani T, Lungu S, Malembo L, Rukuni D, Simwaza PP, Rarieya M, Maghembe JA (1998). Choice of priority indigenous fruits for domestication in southern Africa: summary of case studies in Malawi, Tanzania, Zambia and Zimbabwe. In: Maghembe JA, Simons AJ, Kwesiga F, Rarieya MM (eds) Selecting indigenous fruit trees for domestication in southern Africa: ICRAF, Nairobi Kenya. pp. 1-39.

Kadzere I, Watkins CB, Merwin IA, Akinnifesi FK, Saka JDK (2006). Harvest date affects color and soluble solids concentrations (SSC) of *Uapaca kirkiana* (Muell. Arg.) fruits from natural woodlands. Agroforest. Syst. 69: 167-173.

Kandji ST, Verchot L, Mackensen J (2006). Climate change and variability in southern Africa: Impacts and adaptation in the agricultural sector. Nairobi: UNEP and World Agroforestry Centre. p. 35.

Kwesiga F, Mwanza S (1995). Underexploited Wild Genetic Resources: the case of indigenous fruits in Eastern Zambia. In: Maghembe JA, Ntupanyama Y, Chirwa PW (eds). Improvement of Indigenous Fruit Trees of the Miombo Woodlands of Southern Africa. International Centre for Research in Agroforestry, Nairobi, Kenya, pp. 100-112.

Lee SK, Kader AA (2000). Pre-harvest and post-harvest factors influencing Vitamin C content of horticultural crops. Postharvest Biol. Technol. 20: 207-220.

Lu Z, Fleming HP, McFeeters RF (2002). Effect of fruit size on fresh cucumber composition and the chemical and physical consequences of fermentation. J. Food Sci. 67(8): 2934-2939.

Luo Y (1996). Preservation of apple slices using ascorbic acid and 4-hexaylresorcinol. Int. J. Food Sci. Technol. 2(5): 315-321.

Mithöfer D, Waibel H (2003). Income and labour productivity of collection and use of indigenous fruit tree products in Zimbabwe. Agroforest. Syst. 59:295-305.

Mithöfer D (2005) Economics of Indigenous Fruit Tree Crops in Zimbabwe. PhD Thesis, Department of Economics and Business Administration, University of Hannover, Hannover, Germany.

Mithöfer D, Waibel H, Akinnfesi FK (2006). The role of food from natural resources in reducing vulnerability to poverty: a case study from Zimbabwe. Paper presented at the 26th Conf. Int. Assoc. Agric. Econ. (IAAE), August 12-18, 2006, Queenland, Australia.

Potter NN, Hotchkiss JH (1998). Food Science. A Chapman Hall Food Science Book, Fifth Edition. Aspen Publishers, Inc. Gaithersburg, Maryland, USA.

Saka JDK (1995). The nutritional value of edible indigenous fruits: present research status and future directions. In: Maghembe JJ, Ntupanyama Y, Chirwa PW (eds). Improvement of indigenous Fruit Trees of the Miombo Woodlands of Southern Africa. International Centre for Research in Agroforestry, Nairobi, Kenya. pp. 50-57.

Weisis W, Buchinger J (2003). Solar drying: establishment of a production, sales and consulting infrastructure for solar thermal plants in Zimbabwe. pp. 4-22.