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Sensory evaluation of different preparations of cassava leaves from three species as a leafy vegetable

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Cassava leaves are largely consumed in Africa and are among the top three African indigenous vegetables rich in nutrients. Leaves from bitter (*Manihot utilissima*), sweet (*Manihot dulcis*) and wild (*Manihot glaziovii*) species of cassava were cooked by boiling in salted (sodium bicarbonate and table salt) water with the addition of palm oil and ground-nut paste, following processing by "pounding", "pounding and then drying" and, "drying and then pounding". The drying was done in tunnel solar drier at temperature of 65°C on average. Nine samples (three species x three processing methods) were evaluated by 31 panelists, using a five point hedonic scale, where 5 = like very much and 1= dislike very much. Cassava species affected significantly (p = 0.0047; 0.0206) scoring for texture and overall acceptability, respectively, but not for colour, aroma and taste. Processing method highly significantly (p< 0.0001) affected all the sensory attributes scoring. Leaves from all three species were liked as leafy vegetable, except when pounded after drying.

Key words: Cassava leaves, cassava species, sensory characteristics, tunnel solar drying, processing methods, Rwanda.

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is one of the staple food crops in Africa, it is a rainy fed crop grown mainly in humid and sub humid regions, but being particularly suited to conditions of low nutrients availability of soils and able to survive drought, Cassava became one of the most important food crops in almost entire countries within the tropics (Huzsvai and Rajkai, 2009; El-Sharkawy, 2007). For instance in Rwanda, cassava is the third among main food crops after banana and sweet potatoes, and is one of the priority crops that are being promoted for economic development and poverty reduction in the agricultural sector (MINECOFIN, 2007). In some countries of West and Central Africa, cassava roots and leaves are the basic foods. The Congolese consider the cassava as "all sufficient" because the cassava starchy roots are complemented nutritionally by cassava leaves, which are good source of protein, vitamins and mineral (Bradbury and Denton, 2011). Austin et al. (2009) after realizing the value and utilization of cassava leaves as green vegetable, he placed them among Rwanda's high value vegetables that have potential on domestic, regional and international markets.

Cassava leaves are among the top three African indigenous vegetables rich in nutrients. They are the second in β-carotene after *Moringa oleifera*, the second in vitamin C after *Moringa stenopetala*, the third in vitamin E after *M. stenopetala* and *M. oleifera,* the third in zinc after *Pterocarpus mildbraedii* and *M. oleifera,* the third in antioxidant activity after *Adansonia digitata* and *Rorippa madagascariensis* and the third in total phenolic after

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R. madagascariensis and *A. digitata* (Shackleton et al., 2009). Micronutrients, as well as the many non-nutrient phytochemicals in vegetables are associated with health maintenance and prevention of chronic diseases (Yang and Keding, 2009; Steinmetz and Potter, 1996). For that healthy and nutrition importance, cassava leaves consumption may be improved by preservation methods that can increase its availability and quality.

Cassava leaves, like many other leafy vegetables, are generally seasonal with surpluses in the rainy season and scarcity with high costs in the dry season. Their perishability causes a considerable amount of post-harvest losses in rainy season. To minimize the losses and stabilize availability and price in different markets and seasons, appropriate preservation methods, affordable to rural communities, are needed. According to the study of Thomas (2008), spoilage of food is due to three main causes: Microorganisms, enzymes and chemical reactions. Drying, especially sun-drying is among the oldest and cheapest preservation methods that slow down or completely stop food deterioration by removing available water, the principal factor of food deterioration. As reported by Umuhozariho et al. (2011), in some rural areas of Rwanda, especially in dry regions, where cassava is a main food crop, leaves are dried on mats in open air, either pounded or un-pounded, for increasing shelf life. However, only fresh cassava leaves are sold in different local markets in villages, cities and super markets, the dry products being consumed at family levels. To stimulate people to process market oriented product, the dry cassava leaves need to be tested for physical quality and acceptability.

The direct exposure to sunlight is known to reduce the quality (colour and vitamin contents) of the final product (MMA, 2008). The product is open to various contaminations such as dust, insects, wetness and rain. Moreover, the process is very dependent on good weather, and the very slow drying rates of the process create the danger of mould growth. In contrast, solar dryers are simple installations that can eliminate the negative effects of open air sun drying and thus seems to be the most promising. Solar drying offers the following advantages over sun drying when correctly designed: Faster drying rate, greater retention of vitamins, especially vitamins A and C, minimizing damage from rain, protection against infection among others, and also some advantages over the conventional drying with respect to cost and adaptability to small scale farmers (Eze, 2010; Ferreira et al., 2008). According to literatures, solar drying gives faster drying rates by heating the air to 10-30°C above ambient temperature, using solar energy collectors with natural or forced airflow inside the dryers, and thus increasing their efficiency (Eze, 2010; Lotfalian et al., 2010; Ferreira et al., 2008). In addition, solar dryers are a promising means for tropical countries to meet their requirements as the available amount of solar energy in most cases is sufficient to cover the energy requirements for small dryers (Eze, 2010).

The present study was conducted to assess the usefulness of tunnel solar drying for preserving sensory qualities of cassava leaves and determine which cassava species and processing procedures are preferable for better physical properties and acceptability, as food relishes after leaves are cooked.

MATERIALS AND METHODS

Materials

Collection of cassava leaves

In April 2012, tender cassava leaves were harvested from three species of cassava, bitter (*Manihot utilissima*), sweet (*Manihot dulcis*) and wild (*Manihot glaziovii*). Varieties named Igicucu, Seruruseke (5280) and ISAR 1961 were chosen for wild, sweet and bitter cassava species respectively (Figure 1). In order to minimize the effects of age, environment and soil types on sensory characteristics, leaves samples of the same age were selected from the same field, Rwanda Agricultural Board (RAB)'s field at the Karama Research Station, in Bugesera District of Eastern Province of Rwanda.

Experimental design of sample preparation

The three cassava species as source of vegetable and three processing methods in a completely randomized design (CRD) were evaluated for sensory attributes in one session. The preparation procedures used to prepare leaves from each cassava species before cooking were: Pounding fresh leaves, drying pounded leaves, and drying un-pounded leaves (Figure 2). In this study, both fresh and dried leaves were pounded using traditional woody mortar and pestle. In addition, leaves were blanched before drying and blanching was carried out according to the method described by Kendall et al. (2010). Thus, leaves were submerged in boiling water for 4 min, and then immediately cooled in tap water at ambient temperature. Before drying, pounded and un-pounded leaves were kept in closed polyethylene bags and were stored on ice in an ice-chest for direct transportation to the solar drying station at Sokoine University of Agriculture, Morogoro, Tanzania.

Drying procedures

Samples of pounded and un-pounded leaves from bitter, sweet and wild cassava were dried to brittle using a tunnel solar dryer (Figures 3 and 4). The complete drying was when sample leaves became entirely brittle. Green vegetables contains less sugar, and can be dried to brittle and water content 4-8%, depending on the type of vegetable (James and Kuipers, 2003). The time taken to complete drying for each sample was noted. The temperature inside the tunnel solar dryer was recorded at 8 a.m., noon and 8 p.m. each day. After drying, samples were packed in plastic materials, sealed and stored in opaque cartons at ambient temperature before cooking for sensory evaluation.

Cooking procedures

Similar cooking procedures were followed for all the nine samples. Thus, processed samples were boiled in salted (sodium bicarbonate and table salt) water, with the addition of palm oil and ground-

Figure 1. Sample leaves from sweet (left), wild (middle) and bitter (right) cassava species.

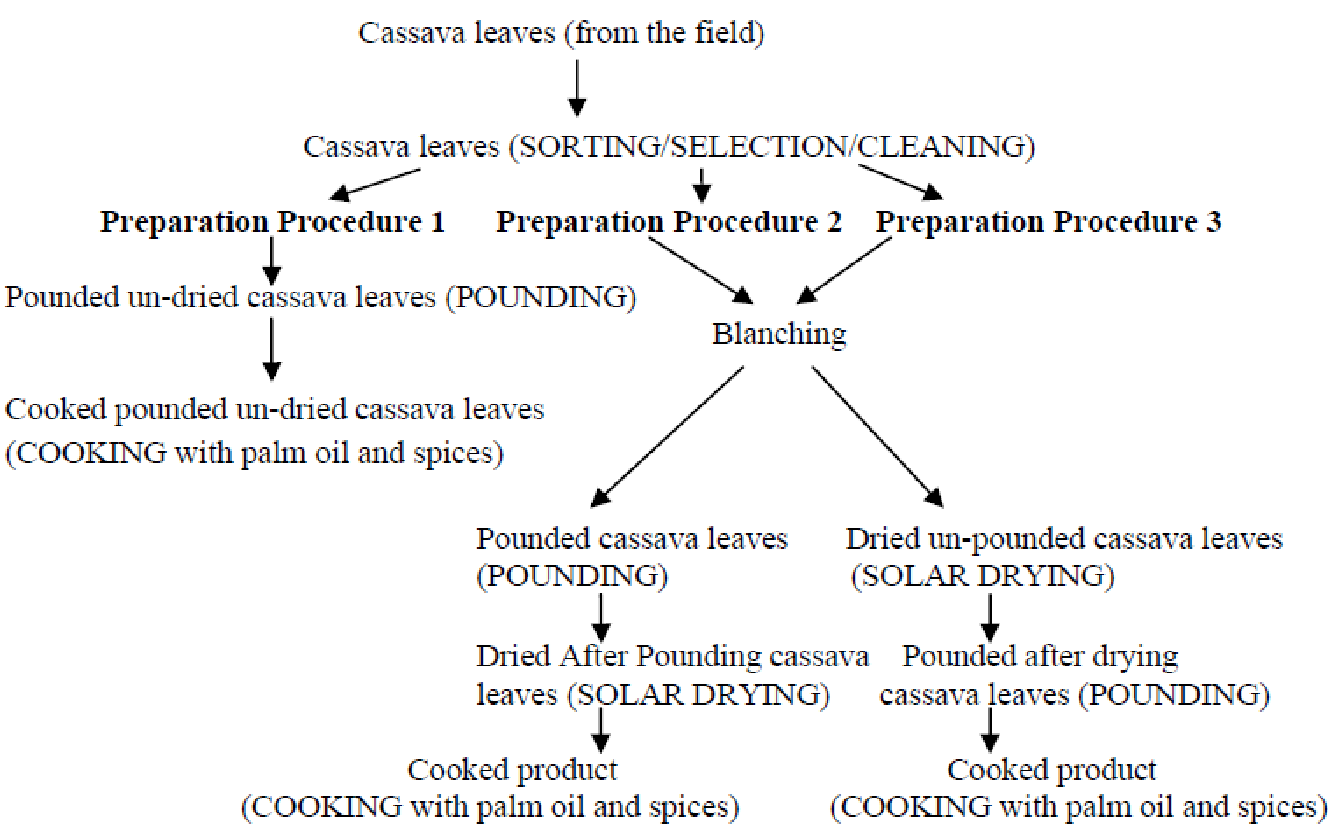

Figure 2. Flow diagram illustrating preparation procedures of cassava leaves.

Figure 3. Tunnel solar dryer covered after placing samples for drying.

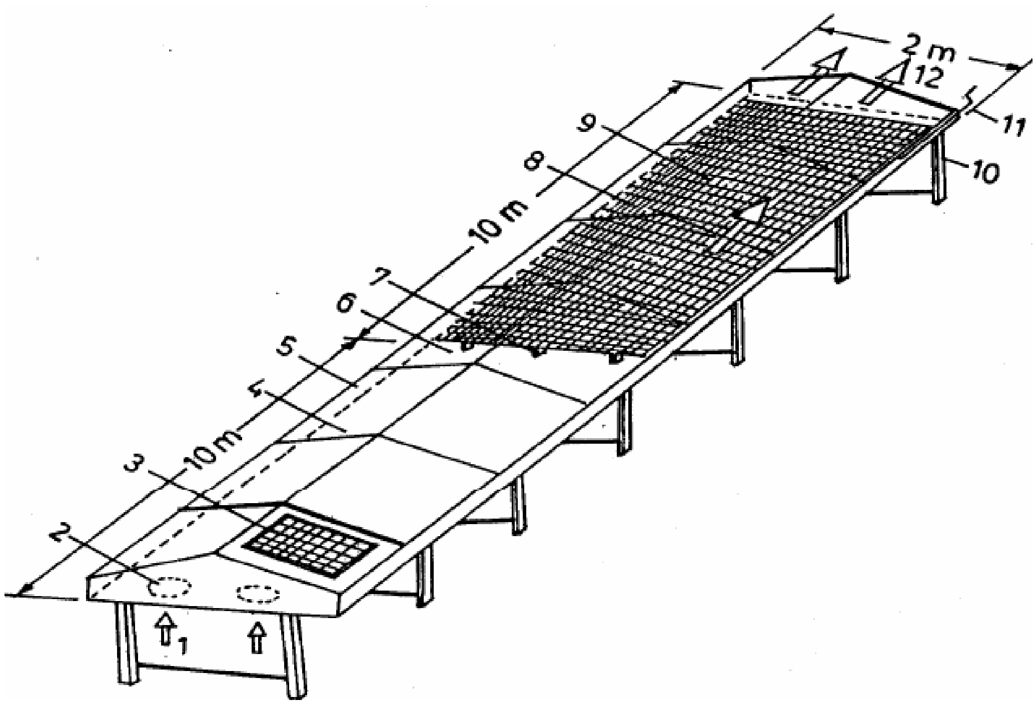

Figure 4. Diagram of the tunnel solar drier. 1, Air inlet; 2, fan; 3, solar module; 4, solar collector; 5, side metal frame; 6, outlet of the collector; 7, wooden support; 8, plastic net; 9, roof structure for supporting the plastic cover; 10, base structure for supporting the tunnel drier; 11, rolling bar; 12, outlet of the tunnel drier.

Table 1. Significance levels from the analyses of variance and for main factors and their interactions on sensory characteristics of cooked cassava leaves as vegetable.

Parameter	Sensory attributes and their p-values				
	Color	Taste***	Aroma	Texture	Overall acceptability
Cassava species	1.1308	0.4890	0.0860	0.0047	0.0206
Processing methods	<.0001	<.0001	<.0001	<.0001	<.0001
Species x methods	0.7526	-	0.0312	0.0733	0.0502
Age group	0.0010	0.1581	<.0001	0.0013	0.0007
Gender	0.9012	0.5898	0.8476	0.0003	0.9040
Age group x Gender	0.1246	-	0.0081	0.0597	0.0908
R^2	0.78	-	0.85	0.90	0.88
CV	9.36	-	10.70	6.65	9.50

**R^2: Coefficient of determination; CV: coefficient of variation; ***Kruskal Wallis test rather than ANOVA and thus no R^2 nor CV.

nut paste, for about 45 min.

Sensory evaluation

A panel of 31 adults (aged above 21 years old), were purposively selected for sensory evaluation. All the participants were familiar with cassava leaves meals even if they were oriented on making inferences and recording the scores for each sample. The panel comprised of females and males of age ≥ 21 years old. A five point hedonic scales as described by Larmond (1977) were used, where 5 = like very much, 4 = like moderately, 3 = neither like nor dislike, 2 = dislike moderately and 1 = dislike very much. The nine samples were served in identical containers, coded with 3 digit random numbers and presented to panellists in one session. The sensory attributes of interest were colour, taste, texture or mouth feel, aroma and overall acceptability. Necessary precautions were taken to reduce crossover effects by selecting greater number of interested panellists rather than motivating panellists and using small number and repeating preparations. In addition, panellists rinsed their mouths with water before tasting the next sample. Out of the 31 panellists, 61% were females and 39% were males. Their ages ranged between 21 and 57 years. Out of 19 females, 47% were young (< 35years) and 53% aged (≥ 35 years) while among males, 75% were young and 25% aged. The session was held in one of the laboratories of the Faculty of Agriculture, National University of Rwanda (NUR), from 11 a.m. to 14 p.m., in a uniform and natural lighting environment.

Statistical analysis

Data analysed included time of drying, temperature inside the tunnel solar dryer and scores for different sensory attributes per sample. After averaging the scores across the five sensory attributes, the "Kolmogorov-Smirnov" test to assess the normality of the averages was carried out as suggested by Kutner et al. (2005). Multiple ways analysis of variance (ANOVA) was applied to sensory attributes with normally distributed averages and, Kruskal Wallis nonparametric test was done for sensory characteristics with strong departure from normal distribution (Kutner et al., 2005). Statistical Analysis Systems (SAS) software, version 9.2 (SAS Institute, 2008) was used to compute ANOVA (F-test statistics), Fisher's Least Significant Difference (LSD) to separate means, and Kruskal Wallis test. The treatments were judged significantly different and highly significantly different at $p < 0.05$ and $p < 0.01$, respectively.

RESULTS AND DISCUSSION

On average, the temperature inside the tunnel solar dryer was 65°C even if the mean monthly temperature of the area was 25°C. The duration of drying was 14 and 16 h under sunny conditions for un-pounded and pounded cassava leaves, respectively. These times of drying of less than one day under the sunny conditions concurred with reports from several studies that solar dryers improve efficiency and quality of the dried food products by increasing temperature of drying and decreasing period of drying. For a tunnel solar dryer, products receive energy both from hot air supplied from the collectors and from incident solar radiation. This increases the temperature inside the dryer and accelerates the drying process (Almhanna, 2012; Banout and Ehl, 2010; Lotfalian et al., 2010; Medugu, 2010; Ferreira et al., 2008).

The effect of processing methods, cassava species, panellists' gender and ages, and their pair wise interactions on various sensory attributes are shown in Table 1. Kolmogorov-Smirnov test indicated that only taste score averages showed a strong departure from normality and Kruskal Wallis test was done. Processing method had high ($p< 0.0001$) significant effects on all the sensory characteristics (colour, taste, aroma, texture and overall acceptability). Cassava species did not significantly influence colour, aroma and taste. In contrast, the species significantly ($p = 0.0206$) influenced overall acceptability and highly significantly ($p = 0.0047$) influenced texture of cooked relishes. Cassava species and processing methods interaction effects were significant for aroma with $p = 0.0312$. Age group of panellists had considerable effects on scoring of different sensory attributes with p-values of 0.0010, < 0.0001, 0.0013 and 0.0007 for color, aroma, texture and overall acceptability, respectively. Gender did not have any significant effect on the averages of the colour, taste, aroma and overall acceptability scoring but highly

Table 2. Means for sensory characteristics for leaves from different cassava species and processing methods.

Parameter		Sensory attributes and their scores				
		Colour	Taste	Aroma	Texture	Overall acceptability
Species	Bitter	4.04 [a]	3.72 [a]	3.71 [a]	3.79 [a]	3.77 [a]
	Sweet	4.03 [a]	3.95 [a]	3.95 [a]	3.86 [a]	3.85 [a]
	Wild	3.76 [a]	3.57 [a]	3.57 [a]	3.64 [b]	3.46 [b]
Processing methods	Dried and then pounded	3.40 [c]	2.90 [c]	2.90 [c]	3.06 [c]	2.87 [c]
	Fresh	4.58 [a]	4.36 [a]	4.38 [a]	4.28 [a]	4.45 [a]
	Pounded and then dried	3.86 [b]	3.94 [b]	3.95 [b]	3.65 [b]	3.76 [b]
Age groups	Aged (≥35)	4.17 [a]	3.91 [a]	4.07 [a]	3.81 [a]	3.91 [a]
	Young (<35)	3.71 [b]	3.55 [b]	3.41 [b]	3.52 [b]	3.48 [b]
Gender	Female	3.93 [a]	3.75 [a]	3.73 [a]	3.83 [a]	3.70 [a]
	Male	3.95 [a]	3.71 [a]	3.76 [a]	3.49 [b]	3.69 [a]

For each sensory characteristic, within column, values with the same letter were not significantly different ($p<0.05$).

influenced texture scoring with a p-value of 0.0003. Age group and gender interaction effects were highly significant ($p = 0.0081$) for only aroma.

Cassava species were equally liked for colour, taste and aroma by panellists (Table 2). Texture and overall acceptability were rated differently with sweet and bitter species being equally liked and the wild species the least preferred (Table 2). During pounding, it was observed that fresh wild cassava leaves were juicier when compared to sweet and bitter. The crude water made pounding hard and particles larger. The less liked texture has been attributed to the larger particles after pounding and cooking. The study showed that leaves from sweet and bitter cassava species were liked more than those from the wild species, although Umuhozariho et al. (2011) reported earlier that leafy vegetable of wild cassava species were more utilized as human food in Rwanda. The reason may be that authors were concerned with consumer habits with respect to cassava leaves which were more subjective, and one of the reported reasons was the availability of wild cassava leaves as the farmers are more interested in root production than leaves for bitter and sweet species. This is the first study of sensory comparison of leaves from different species of cassava in Rwanda, clearly showing leaves from wild cassava species are less preferred by panellists compared to those from cultivated species.

Panellists above 35 years of age liked all preparations of the vegetables for all the sensory attributes more than those less than 35 years (Table 2). This was not surprising as Larmond (1977) mentioned age and sex of panellist among important factors that can influence result in sensory test.

Colour of the different vegetable preparations differed significantly according to processing methods, but not to species (Table 2). In this study, all samples were cooked in salted (sodium bicarbonate and table salt) water, but blanching had been done in un-salted water before drying. Cooked fresh leaves became bright-green while dried ones were dark-green. Heating green vegetables in an alkaline solution such as sodium bicarbonate ($NaHCO_3$) make the cooking water slightly basic, the magnesium ion is retained in the chlorophyll and the colour is a bright-green. In contrast, when vegetables are heated without the alkaline, such as blanching before drying as in the present study, part of their cells are disrupted and some organic acids are released and react with chlorophyll. The reaction with the acids replaces the magnesium atom (Mg) of chlorophyll with a hydrogen atom (H) to form an unattractive dark-green pigment pheophytin (FAO, 1995). The unlikeable colour was probably due to the formation of pheophytin in dry cooked cassava leaves.

Fresh cassava leaves were the most liked, followed by the “pounded and then dried”. In another investigation, Mepba et al. (2007) found that panellists preferred fresh to dry vegetable soup. “Dried before pounding” was the least liked for all sensory attributes (Table 2). The poor rating of “dried before pounding” products for all sensory characteristics were attributed to their bitterness as commented by panellists.

Taste and aroma were highly correlated with overall acceptability, with $r = 0.93$, $p<0.0001$ and $r = 0.91$, $p<0.0001$, respectively. Taste and aroma were also much correlated ($r = 0.90$, $p<0.0001$) (Table 3). High correlation between taste, aroma and overall acceptability is not surprising. Taste perception has been suggested to play a key role in determining individual food preferences and dietary habits (IUFoST, 2012; Garcia- Bailo et al., 2009). Equally, Clark (1998) reported a similar relation of a strong influence of taste and aroma (odour and flavour) on food acceptability, and that the two sensory characteristics are considered the key of food choice. The high positive correlation among the sensory characteristics, especially taste, aroma and overall acceptability (Table 3), suggests that the unlikeable bitter

Table 3. Linear correlation among sensory characteristics of processed leafy vegetables from three cassava species.

Sensory attribute		Colour	Taste	Aroma	Texture	Overall acceptability
Colour	r	1	0.8198	0.7764	0.7619	0.8881
	Prob > |r|		<.0001	<.0001	<.0001	<.0001
Taste	r		1	0.9059	0.8673	0.9393
	Prob > |r|			<.0001	<.0001	<.0001
Aroma	r			1	0.7949	0.9109
	Prob > |r|				<.0001	<.0001
Texture	r				1	0.8569
	Prob > |r|					<.0001
Overall acceptability						1

r, Linear correlation coefficient; Prob > |r|, probability of having a correlation factor equal to or larger than the obtained r.

taste could be the only source of "dried before pounding" vegetables rejection. Also when leaves were pounded after they were dried, particles were very fine and gave a soup-like texture after cooking, which was less liked by panellists.

Bitterness in the "dried before pounding" cassava leaves may possibly be attributed to high levels of residual cyanogens. Karltun et al. (2004) demonstrated a strong correlation between bitter taste and cyanogen (HCN) potential in cassava. Awoyinka et al. (1995) reported that blanching does not change HCN-potential, but pounding or grinding reduces both HCN-potential and tannins. As in the present study, the leaves were blanched to limit degradation of nutrients and colour, endogenous enzymes, linamarase and hydroxynitrile lyase, important in linamarin and acetone cyanohydrin hydrolysis, were also deactivated. But significantly, linamarin and the break down product of linamarin, cyanohydrin can decompose spontaneously at high temperatures or pH 4 and above, to release HCN, harmful to human health, but volatile during preparations (Cereda and Mottos, 1996; Mkpong et al., 1990). Cyanogen levels were not analysed in this study, an additional study for safety of the products is necessary.

Conclusion

Leaves from all the three species of cassava found in Rwanda (bitter, sweet and wild) were liked for food as green vegetables. However, leaves from wild species were less preferred for texture and overall acceptability than those from sweet and bitter species. Processing methods were a strong source of differences in sensory attributes and fresh leaves were the best, followed by "pounded before drying" leaves for all the sensory attributes. Therefore, for marketability and preservation issues, cassava leaves can be processed by solar drying, and preferably pounded before they are dried for a better taste and texture. Blanching in alkaline water is appropriate to preserve the light-green colour, preferred by consumers. Though un-pounded leaves dried faster and pounding after drying was easier, they were poorly rated, especially for taste, aroma and overall acceptability. An additional study on cyanide and nutrients of the processed cassava leaves is highly recommended to ensure nutritional quality and safety of the products for human consumption.

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