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COMMUNICATION

Effect of Processing Methods on the In Vitro Protein Digestibility and Vitamin Content of Edible Winged Termite (*Macrotermes subhylanus*) and Grasshopper (*Ruspolia differens*)

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Abstract The influence of processing methods of toasting and solar drying on the in vitro protein digestibility and vitamins content of edible winged termites, green grasshoppers, and brown grasshoppers consumed in Siaya, district of Kenya, was determined using standard methods. Analysis was done on fresh, toasted, toasted dried, and fresh dried insect samples. There was no significant change ($p>0.05$) in protein digestibility in the termite samples, while a significant decrease ($p\leq0.05$) in the grasshopper samples was observed on toasting and drying. There was a significant reduction ($p\leq0.05$) in riboflavin content with 4.18 mg/100 g in fresh termites, 2.76 mg/100 g in toasted termites, 2.26 mg/100 g in fresh dried termites, and 1.50 mg/100 g in toasted dried termites on processing. There was also a significant reduction ($p\leq0.05$) in niacin content in the grasshoppers with 3.61 mg/100 g in fresh green grasshopper, 3.28 mg/100 g in toasted green grasshopper, 3.22 mg/100 g in fresh dried green grasshoppers, and 3.06 mg/100 g in toasted dried green grasshoppers. A significant reduction ($p\leq0.05$) in retinol content with 2.24 μg/g in fresh termites, 1.56 μg/g in toasted termites, 1.02 μg/g in toasted dried termites, and 0.98 μg/g in fresh dried termites was also reported. The processing methods of the insects affected their nutrient potential as evidenced by the changes in protein digestibility and vitamins content. Therefore, optimal processing methods need to be investigated even as we promote commercialization of these insects.

Keywords Processing · Edible insects · Protein digestibility · Vitamin

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Introduction

There are more than 400 known species of edible insects (Allotey and Mpuchane 2003). Insects are an important food source for humans, and references to their nutritional value are found in a number of articles across a range of scientific disciplines (DeFoliart 1991, 1995, 1999; Kinyuru 2009). In Africa, many species of insects have been used as traditional foods among indigenous people and have played an important role in the history of human nutrition (Morah 1998; Omotoso 2006). Insects were an equally important resource for the Indians of Western North America, who like other indigenous groups, expended much organization and effort in harvesting them (Sutton 1988; Huis 1996).

Edible insects have been reported to contain essential nutrients to the human diet. Different authors have reported high protein content of edible insects and significant amounts of vitamins (Kinyuru 2009; Barker et al. 1998; Finke 2002). The caterpillar, *Usta terpsichore,* from Angola was found to be a rich source of thiamin and riboflavin (Oliveira et al. 1976). The palm weevil larva, *Rhynchophorus phoenicis,* consumed in Nigeria was found to contain high levels of thiamin and riboflavin (Banjo et al. 2006). In Zaire, Kodondi et al. (1987) analyzed three species of caterpillars prepared by the traditional techniques of smoking and drying

and found them to be high in riboflavin and niacin but low in thiamin and pyridoxine.

Edible winged termites *(Macrotermes subhylanus)*, locally known as "agoro," and the long-horned grasshopper (*Ruspolia differens),* locally known as "senesene," are an integral part of human diet in Lake Victoria, region of Kenya. The grasshopper exhibits color polymorphism either as green or brown though other color forms have been reported (Bailey and McRae 1978). Depending on seasonal availability, the insects are traditionally consumed as a snack—fresh, toasted, or even sun-dried.

This research was, therefore, carried out in order to ascertain the influence locally utilized processing methods of toasting and solar drying methods on the in vitro protein digestibility and vitamin content of the termite and grasshoppers and hence, the nutritional potential of the processed insects.

Materials and Methods

The information on the insects was acquired through personal observation and informants living in Kanyaboli and Kadenge sublocation of Siaya district, Nyanza province, Kenya. A total of five villages were selected namely—Urembo, Uradi, Wang' Chieny, Nyaseda, and Liganwa. A total of ten families were selected, and one adult from each family was a key informant. The informants helped to identify the collection sites of the insects used in this study.

The insects collected were available during the time of the fieldwork during the short rains season from March to May, and the long rain season from September to December in 2007 and 2008. Termites were attracted by light from a lantern lamp causing them to fall in large swarms that were collected and put in a clean container. The longhorn grasshoppers were collected early in the morning between 6:00 a.m. to 7:00 a.m. when they were inactive and therefore, could not fly and put in a clean container. The samples were stored in cool boxes with dry ice and transported to the Food Biochemistry laboratory, Jomo Kenyatta University of Agriculture and Technology (JKUAT) for laboratory analysis within 12 h of collection. The analysis commenced immediately upon arrival in the laboratory. The wings of the whole insects were plucked off manually before laboratory analysis. Taxonomic identification of the insect species was done by an entomologist at Maseno University.

Fresh samples were analyzed after plucking the wings. Another sample of fresh samples (200 g) was toasted with their own oil in a stainless steel cooking pan over an open flame for 5 min at an approximate temperature of 150 °C. The toasting was done according to the traditional practice at the villages where the insects are toasted in their own oil. To obtain toasted dried samples, 100 g of previously toasted samples were cooled to room temperature on a perforated plastic pan and then subjected to solar drying immediately. Fresh dried samples were obtained by taking 100 g of fresh samples and subjecting them to solar drying. Solar drying was done in JKUAT using a locally fabricated solar drier. The samples were evenly spread on the wire mesh trays on the drier and turned several times to dry. The drying temperature was approximately 30 °C with a relative humidity of approximately 40%. The moisture and fat contents of the fresh and processed samples used for analysis were as shown in Table 1 as determined by AOAC (1996) methods.

In vitro protein digestibility of the insect samples was determined by the method outlined by Saunders et al. (1973) as modified by Nafisa et al. (2008), water-soluble vitamins (Ekinci and Kadakal 2005) while retinol and tocopherol contents were determined according to the method outlined by Barker et al. (1998). Data were subjected to analysis with SAS software (SAS 2001). Analysis of variance with multiple comparisons using Tukey's studentized range test was used to determine the significance of differences among treatments. The level of significance was set at $p<0.05$.

Results and Discussion

There was a general decline in in vitro digestibility of the protein with the fresh insect samples having the highest protein digestibility (Table 2). However, the decline of digestibility in termite (*M. subhylanus*) on heat processing of fresh (90.49%), toasted (90.36%), toasted dried (90.13%), and fresh dried (90.11%) samples was not significant ($p<0.05$), but the reduction was significant in the green and brown grasshoppers (*Ruspolia differens*) samples.

Depending on the processing conditions, heat processing may reduce or increase protein digestibility. Exposure to denaturation temperatures may increase digestibility of native proteins by unfolding the polypeptide chain and rendering the protein more susceptible to digestive enzymes (Opstvedt et al. 2003). On the other hand, when proteins are exposed to some heat treatments, digestibility may be reduced due to formation of disulphide bonds in the protein (Stanley 1998; Oria et al. 1995). In addition, Nafisa et al. (2008) reported that toasting and boiling of the tree locust increased tannins and phytate content in the whole insect, and this resulted to a reduction in in vitro protein digestibility in boiled and fried sample. In addition to digestibility, other protein properties have also been affected by similar processing methods. Babiker et al. (2007) studied the functional properties of the Sudanese

Table 1 Moisture and fat contents (wet basis) of termite (*Macrotermes subhylanus*) and grasshoppers (*Ruspolia differens)* on processing

Insect	Sample	Moisture (g/100g)	Fat (g/100g)
Termite	Fresh	58.3	19.8
	Toasted	50.7	21.4
	Toasted dried	10.0	39.0
	Fresh dried	9.9	42.3
Green grasshopper	Fresh	66.2	16.3
	Toasted	54.6	20.0
	Toasted dried	9.8	39.6
	Fresh dried	9.9	43.1
Brown grasshopper	Fresh	72.3	12.8
	Toasted	65.3	14.6
	Toasted dried	9.9	37.9
	Fresh dried	10.0	41.2

tree locust protein and found that protein solubility was significantly reduced by frying leading to use of solubility enhancers to improve the solubility in locust flour.

Processing reduced the protein digestibility though the values were still found to be comparable to some reported of some food proteins. The level of digestibility observed in the fresh termites (90.49%), green grasshoppers (82.34%), and brown grasshoppers (85.67%) were found to compare well with the values reported in conventional animal and plant protein sources. Bodwell et al. (1980) reported protein digestibility values of 89% for whole beef, 90% for porks, 78% for turkey, and 85% for salmon.

The influence of processing on the vitamins content from the insects is shown (Tables 3, 4 and 5). There was a general decrease in all the vitamins content evaluated from the fresh, toasted, fresh dried, and toasted dried samples. There was a significant reduction ($p \leq 0.05$) in riboflavin content on toasting and subsequent solar drying in the two species of insects as compared with the fresh samples. Toasting of termite samples at 150 °C for 5 min led to a 34% reduction in riboflavin content in comparison to fresh samples. However, subsequent solar drying at 30 °C of the toasted sample led to a much higher loss (64%) in riboflavin content as compared to the fresh dried sample (46%) in comparison to fresh samples. This trend was also observed for all other vitamins on the test samples under similar processing conditions. A significant reduction ($p \leq 0.05$) in niacin and ascorbic acid content in the grasshoppers were observed on processing (Tables 3, 4 and 5). Ascorbic acid is highly susceptible to heat and light, therefore, toasting at 150 °C and solar drying the green grasshopper samples reduced it significantly ($p \leq 0.05$) by two low levels (0.23 mg/100 g) compared to the fresh samples (0.62 mg/100 g).

Retinol content in the toasted, toasted dried, and fresh dried samples were significantly different ($p \leq 0.05$) in termite samples though there was no significant difference ($p > 0.05$) between toasted dried (1.02 μg/g) and fresh dried (1.02 μg/g) samples as shown in Table 3. There was no significant difference ($p > 0.05$) in α-tocopherol between fresh (51.68 μg/g) and toasted (41.42 μg/g) termite samples, as well as between toasted dried (36.97 μg/g) and fresh dried (35.92 μg/g). There was a significant reduction of retinol during heat processing and solar drying on the brown grasshoppers studied (Tables 5). The toasted samples showed an 18% reduction, fresh dried samples had a 30%, while the toasted dried sample showed a 60% reduction with refernce to the fresh samples.

Dehydration of foods may result in loss of vitamins and other depending on the food type (Gareth et al. 1990; Negi and Roy 2001), as well as other food properties (Falade and Omojola 2008). The loss in the water-soluble vitamins content in this study may have resulted from oxidation on exposure to light and heat, effects of the processing temperatures or due to enzymatic and chemical degradation, especially in the presence of traces of heavy metal ions, which positively catalyzes the chemical degradation (Ana and Lia 1997). The rate of vitamin destruction is accelerated by increase in temperature and duration of heating. This is

Table 2 In vitro protein digestibility (%) of termite (*Macrotermes subhylanus*) and grasshopper (*Ruspolia differens*)

	Termite (*M. subhylanus*)	Green grasshopper (*R. differens*)	Brown grasshopper (*R. differens*)
Fresh	90.49 ± 0.48^{a}	82.34 ± 0.34^{a}	85.67 ± 0.69^{a}
Toasted	90.36 ± 0.95^{a}	80.11 ± 1.09^{b}	83.68 ± 1.00^{b}
Toasted dried	90.13 ± 0.67^{a}	76.39 ± 0.44^{c}	82.34 ± 0.72^{bc}
Fresh dried	90.11 ± 1.06^{a}	79.64 ± 0.59^{b}	81.11 ± 1.02^{c}

Values on the same row followed by the same superscript are not significantly different ($p > 0.05$)

$n = 6$

Table 3 Vitamin content of termite (*Macrotermes subhylanus*) on processing

Vitamin	Samples			
	Fresh	Toasted	Fresh dried	Toasted dried
Pyridoxine (mg/100 g)	0.27±0.01[a]	0.26±0.01[a] (4)	0.24±0.05[b] (11)	0.19±0.01[c] (30)
Folic acid (mg/100 g)	0.19±0.01[a]	0.12±0.01[b] (37)	0.10±0.01[c] (47)	0.09±0.01[c] (53)
Ascorbic acid (mg/100 g)	0.73±0.20[a]	0.61±0.20[b] (16)	0.33±0.01[c] (55)	0.25±0.01[d] (66)
Niacin (mg/100 g)	2.80±0.10[a]	2.20±0.20[b] (21)	2.07±0.15[d] (26)	1.66±0.20[c] (41)
Riboflavin (mg/100 g)	4.18±0.30[a]	2.76±0.15[b] (34)	2.26±0.20[c] (46)	1.50±0.10[d] (64)
Retinol (μg/g)	2.24±0.19[a]	1.56±0.10[b] (30)	0.98±0.05[c] (56)	1.02±0.10[c] (54)
α-Tocopherol (μg/g)	51.68±4.00[a]	41.42±4.10[b] (20)	35.92±4.50[c](30)	36.97±3.50[c] (28)

Values in brackets indicate a percentage decrease in vitamin content

Values on the same row followed by the same superscript are not significantly different ($p>0.05$)

$n=6$

Table 4 Vitamin content of green grasshopper (*Ruspolia differens)* on processing

Vitamin	Samples			
	Fresh	Toasted	Fresh dried	Toasted dried
Pyridoxine (mg/100 g)	0.44±0.05[a]	0.42±0.05[a] (5)	0.40±0.05[b] (9)	0.39±0.03[b] (11)
Folic acid (mg/100 g)	0.99±0.05[a]	0.56±0.01[b] (43)	0.34±0.05[c] (66)	0.32±0.01[c] (68)
Ascorbic acid (mg/100 g)	0.62±0.15[a]	0.50±0.10[b] (19)	0.35±0.02[c] (44)	0.23±0.01[d] (63)
Niacin (mg/100 g)	3.61±0.20[a]	3.28±0.15[b] (9)	3.22±0.02[b] (11)	3.06±0.01[c] (15)
Riboflavin (mg/100 g)	1.20±0.02[a]	0.93±0.03[b] (23)	0.84±0.05[c] (30)	0.68±0.05[d] (43)
Retinol (μg/g)	1.06±0.05[a]	0.82±0.07[b] (23)	0.69±0.01[c] (35)	0.62±0.01[c] (42)
α-Tocopherol (μg/g)	161.45±5.00[a]	139.16±4.80[b] (14)	135.92±5.20[b] (16)	135.99±2.50[b] (16)

Values in brackets indicate a percentage decrease in vitamin content

Values on the same row followed by the same superscript are not significantly different ($p>0.05$).

$n=6$

Table 5 Vitamin content of brown grasshopper (*Ruspolia differens)* on processing

Vitamin	Samples			
	Fresh	Toasted	Fresh dried	Toasted dried
Pyridoxine (mg/100 g)	0.16±0.05[a]	0.15±0.05[ab] (6)	0.14±0.02[b] (13)	0.13±0.01[b] (19)
Folic acid (mg/100 g)	0.92±0.05[a]	0.52±0.20[b] (43)	0.35±0.00[c] (62)	0.32±0.30[c] (65)
Niacin (mg/100 g)	3.22±0.40[a]	2.98±0.30[ab] (7)	3.01±0.40[b] (6)	2.17±0.20[c] (33)
Ascorbic acid (mg/100 g)	0.16±0.10[a]	0.12±0.05[b] (25)	0.12±0.10[b] (25)	0.10±0.04[bc] (38)
Riboflavin (mg/100 g)	1.36±0.10[a]	1.05±0.05[b] (23)	0.96±0.05[b] (29)	0.42±0.07[c] (69)
Retinol (μg/g)	2.21±0.25[a]	1.82±0.20[b] (18)	1.55±0.05[c] (30)	0.89±0.05[d] (60)
α-Tocopherol (μg/g)	170.60±4.80[a]	160.12±2.20[b] (6)	155.46±5.00[c] (9)	154.66±5.00[c] (9)

Values in brackets indicate a percentage decrease in vitamin content

Values on the same row followed by the same superscript are not significantly different ($p>0.05$)

$n=6$

evidenced by a greater loss in toasted dried samples than fresh dried samples. A recent study has shown that cooking, e.g., toasting, significantly decreased the concentration of water-soluble vitamins in the seeds of African oil bean, melon, castor oil, and fluted pumpkin (Onyeike and Onwuka 1999). Losses in vitamins during drying of other foods have also been reported (Mziray et al. 2000).

Conclusion

The processing methods were found to decrease the nutrient content of the edible insects as evidenced by the changes in the in vitro protein digestibility and vitamins content. There is, therefore, a need to optimize these methods in order to reduce the nutrient losses and therefore, give a higher nutritional benefit to the consumers.

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