International Food Research Journal 25(4): 1592-1599 (August 2018)
Journal homepage: *http://www.ifrj.upm.edu.my*

# Development and quality evaluation of crackers enriched with edible insects

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**Article history**

*Received: 15 April 2017*
*Received in revised form: 25 June 2017*
*Accepted: 27 June 2017*

**Keywords**

*Edible insects*
*Enriched crackers*
*Acceptability*
*Nutrient quality*

**Abstract**

Insects are rich in essential nutrients; their use in food fortification is emerging as a means of producing nutritious and acceptable food products for human consumption. The study was undertaken to develop crackers enriched with ground insects; evaluate effect of insect inclusion and processing temperature on acceptability and nutritional quality. Insects (crickets, soldier and winged termites) were dried and ground for production of crackers. Crackers were evaluated by fifty untrained panelists to screen acceptability by insect species against the control. Subsequently, the most preferred insect species (winged termites) was used to substitute wheat flour at 5, 10 and 15% to determine acceptability and nutrient content by insect proportion. Cracker were finally formulated with the most preferred insect proportion (5%); using ground winged termites oven dried at 90, 120 and 150°C to determine acceptability by drying temperatures and nutrient quality was determined using standard methods. Winged termite enriched crackers were most preferred, comparing favorably with the control. Increased substitution level significantly ($p<0.05$) decreased acceptability of crackers color. Nutrient content per 100 g increased significantly ($p<0.05$) with insect proportion, while nutrient quality reduced significantly ($p<0.05$) with increased temperatures; protein digestibility; 26.23 to 20.56% Fe; 42.26 to 20.79% and Zn solubility 27.63 to 18.32% at 90 and 150°C respectively. Crackers enriched with 5% ground winged termite oven dried at 90°C had good nutrient and sensory qualities. The study envisaged acceptable use of termites in the bakery industry.



## Introduction

The present state of food security in Africa makes it pertinent to search for new food alternatives that could enrich the basic diet and fit within traditional African food habits. Van Huis *et al.* (2013) recommended that in areas where food insecurity is common, edible insects need to be promoted as key foods and feeds for nutritional, cultural and economic reasons. Studies in many parts of Africa suggest that entomophagy is an integral part of the traditional food culture and supplements the diet with quality protein, minerals and essential fats (Christensen *et al*., 2006; Dube *et al*., 2013; Kinyuru *et al.,* 2013; Siemianowska *et al.*, 2013). Indeed insects have played an important part in the history of human nutrition in Africa, Asia and Latin America (Allotey and Mpuchane, 2003). Chen *et al.* (2009) indicated that hundreds of species have been used as human food, which include grasshoppers, caterpillars, beetle grubs and adults, termites, bees, wasps and ant brood, and a variety of aquatic insects. In Uganda, widely eaten insects include termites (*Macrotermes* spp), crickets (*Brachytrupes* spp) and cone-headed grasshoppers *(Ruspolia nitidula)* consumed among many cultures. In the Lango sub-region, insect consumption is part of the cultural diet.

However, in order to increase insect consumption, strategies are required to overcome certain limitations like seasonal availability, consumer acceptability, convenience of products and perishability. This is necessary as the food habits of the people are changing very fast particularly in recent times due to their socio-economic improvements, availability of new sources as a result of food application of enriched, pre-prepared foods for the convenience of the customers. Development of new food products from various sources becomes vital to catch the taste of the different people with diverse food habits. A key component to increase insect consumption is

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to provide processed and enriched insect products that have high nutritional value and also meets the customer expectations (sensory appealing).

Present market trends are indicative of extensive growth in demand for ready-to-cook or ready-to-serve convenience products. Crispy food items like crackers are very common snack all around the world. Crackers are an important product line within the large-scale baking industry, and are a natural fit as portable and convenient foods (Juan *et al*., 2014). 'Cracker' is a generic term used throughout the world and refers to products with very low sugar and moisture content; crackers usually have a high fat content and longer shelf life than most baked foods.

Ayieko *et al*. (2010) developed wheat crackers enriched with flour from edible insects (termites and mayfly) commonly consumed in Lake Victoria region of Kenya and reported that the product was well accepted by the consumer panel. The product was also anticipated to be a better snack than regular biscuits for children. However, there is a dearth of information on the process protocol, sensory and nutritional characteristics of insect enriched crackers. Therefore, the study was undertaken to develop a process for enrichment of crackers with edible insect flour; evaluate the effect of insect flour inclusion levels and processing temperature on sensory acceptability and nutritional quality of crackers. This study was useful in identifying native foods which may be significant in providing affordable and dietary complete constituents.

## Materials and Methods

*Selection of insect species and collection for cracker development*

Edible insects commonly consumed in Lango sub region, located in northern Uganda was used in the study. Selection of insect species for cracker enrichment was guided by availability of the species, frequency of consumption, local preference, market value and perceived nutritional value by the community. This information was obtained from a household survey and focus group discussions that were conducted in the study area. This resulted into selection of three Insect species; winged termites *(Macrotermes bellicosus)*, soldier termites *(Syntermes soldiers)* and crickets (*Brachytrupes* spp.). Taxonomic identification of the insect species was done by an entomologist at Makerere University.

Insects were harvested from the sub-region between April to early May 2013 and transported in iced boxes to the laboratory at the school of Food Technology, Nutrition and Bio engineering, Makerere University for processing. Insects were cleaned, de-winged, de-legged and blanched according to procedures recommended by Menzel and D'Aluisio (1998). Winged termites, soldier termites and crickets were oven dried at 150°C for 10, 20 and 25 minutes respectively. Choice of drying temperature and time were based on the need to crisp dry the insects, induce development of good flavor and aroma following recommendations of Kita and Figiel (2007). Dried insects were allowed to cool, milled and sieved using a 250 µm mesh sieve to fine flour which was used in cracker enrichment. Ingredients used in cracker formulations with the respective quantities are shown in Table 1. Choice of ingredients were in reference to Duncun (2001).

Table 1. Formulations of insect enriched wheat crackers and the control

| Ingredients (g) | Soldier termite-wheat flour crackers | Winged termite - wheat flour crackers | Cricket-wheat flour crackers | Wheat flour crackers (Control) |
|---|---|---|---|---|
| *Soldier termite | 8 | 0 | 0 | 0 |
| *Winged termite | 0 | 8 | 0 | 0 |
| *Cricket flour | 0 | 0 | 8 | 0 |
| Wheat flour | 92 | 92 | 92 | 100 |
| Table salt | 0.8 | 0.8 | 0.8 | 0.8 |
| Table sugar | 3.0 | 3.0 | 3.0 | 3.0 |
| Unsalted butter | 13.0 | 13.0 | 13.0 | 13.0 |
| Flavor | 1.7 | 1.7 | 1.7 | 1.7 |
| baking powder | 0.7 | 0.7 | 0.7 | 0.7 |
| Water | 16.7 | 16.7 | 16.7 | 16.7 |

*are ground insects used to substitute wheat flour in the formulations of crackers

*Development of crackers*

Insect flour was used to substitute 8% of wheat flour in cracker formulation. Choice of substitution level was based on several trials following changes in the dough characteristics; at 8%, the dough color was quite similar to the control, it was easy to roll and shape. Dry ingredients (flour, sugar, salt baking powder and insect flour) were mixed in a large bowel, subsequently semi-solid and liquid ingredients (flavor, butter and water) were added. Mechanical kneading for 10-15 minutes was done for the dough to obtain a still ball appearance. The dough was rolled to a thickness of 1/8 inch on a lightly floured board, using a lightly floured pin. By means of a 2 inch cookie cutter, the dough was cut out and placed on an ungreased cookie sheet and picked on top in several

places with a fork. Baking was done in a pre-heated oven at 200°C for 20 minutes to obtain a light gold color of the crackers as recommended by Duncun (2001). Crackers were cooled at room temperature and packed in vacuum containers.

*Processing, screening and characterization of insect crackers*

Enriched crackers and the control were processed and screened using sensory evaluation to determine insect suitability for cracker development. Sensory acceptability (taste, flavor, color, aroma, crunchiness, texture, appearance and overall acceptability) was determined in a sensory evaluation laboratory by fifty un trained panelists consisting of males and females, who had no history of food allergies and were above 18 years using 9 point hedonic scale (1=dislike extremely, 2=dislike very much, 3=dislike moderately, 4=dislike slightly, 5=neither like nor dislike, 6=like slightly, 7=like moderately, 8=like very much, and 9=like extremely). The insect that produced the most preferred enriched cracker (winged termites) was chosen for the subsequent stage of processing and evaluating effect of insect flour inclusion levels and drying temperature on the sensory acceptability and nutrient quality.

Crackers were formulated by substituting 5, 10 and 15% of wheat flour with winged termite flour; quantities of other ingredients in the formulation were maintained. The resultant crackers were sensory evaluated while the nutrient (protein, energy, Fe and Zn) content was determined using Nutri-survey 2007, a software which calculates the nutrient composition and quantity based on ingredients in the food.

The most preferred proportion (5%) was used to determine the effect of processing temperature on sensory and nutrient quality of crackers. Winged termites were oven dried at 90,120 and 150°C for 10 minutes. Choice of the drying temperatures was guided by finding of Kita and Figiel (2007). Dried termites were milled and used to substitute wheat flour at 5% while quantities of all other ingredients were not altered. Processed crackers were sensory evaluated while nutrient quality (*in-vitro* protein digestibility, energy, and Zn and Fe solubility) was determined using standard procedures.

*In vitro* protein digestibility was determined by digesting about 0.2 g of each sample using a single enzyme (pepsin) according to Butts *et al.* (2012). Total calories was determined using a bomb calorimeter (Gallenkamp Auto Bomb, UK) according to the procedures described by AOAC, (1999) while Iron and zinc solubility was determined using the method of Miller *et al.* (1981).

*Data analysis*

Data on sensory and nutritional characteristics were analyzed using Statistix version 9.0 analytical software. Analysis of Variance (ANOVA) was performed and difference between means were separated using Least Significant Difference (LSD) test at 5% (P=0.05). Results were reported as means ± standard deviations (SD).

## Results

Sensory acceptability of crackers is presented in Table 2. Crackers enriched with termites were generally acceptable to consumers whereas the cricket enriched crackers were not acceptable. Winged termite crackers were most preferred; it ranked highly in most sensory attributes. Its taste, flavor, aroma and crunchiness were not significantly ($p>0.05$) different from the control.

Crackers enriched with 5, 10, 15% of winged termites flour were generally acceptable to the consumers (Table 3). Cracker at 5% enrichment was most preferred (7.30). It ranked highly in color, flavor and taste. Increased substitution level decreased acceptability of crackers appearance significantly ($p<0.05$). Nutrient content per 100 g of crackers increased significantly ($p<0.05$) with increase in the proportion of winged termites in crackers. Protein increased from 13.05 to 16.05 g, energy from 438.05 to 476.75 kcal, Fe from 5.35 to 9.35 mg and Zn from 4.15 to 5.50 mg at 5% and 15% enrichment respectively. Consumption of 25 g of crackers enriched with winged termites (the most preferred) contributes a substantial proportion of the protein, energy, iron and Zinc to the recommended dietary intake of pre-school children (Table 4).

Increasing processing temperature of termite flour did not have a significant ($p>0.05$) effect on sensory attributes and overall acceptability of crackers. However, nutrient quality was significantly ($p<0.05$) affected by processing temperatures (Table 5). Increasing temperature led to reduction in in vitro protein digestibility, Iron solubility and Zinc solubility; and an increase in the energy value. In vitro protein digestibility of the crackers enriched with winged termite flour processed at 90°C was significantly ($p<0.05$) high (26.23%). Energy value was significantly ($p<0.05$) high (519.13 kcal/100 g) at 150°C and low (488.29 kcal/100 g) at 90°C. Iron solubility at 90°C (42.26%) and 120°C (42.73%) did not differ significantly ($P>0.05$), while Zinc solubility varied significantly ($p<0.05$).

Table 2. Sensory attributes of insect enriched crackers and the control

| Sensory attributes | Soldier termites crackers | Winged termites crackers | Crickets crackers | Control* |
|---|---|---|---|---|
| Taste | 5.81±1.65$^{b}$ | 6.22±2.15$^{ab}$ | 4.36±1.94$^{c}$ | 7.25±1.18$^{a}$ |
| Flavor | 5.81±1.91 $^{b}$ | 6.17±1.81$^{ab}$ | 4.42±1.95$^{c}$ | 7.11±1.47$^{a}$ |
| Color | 6.53±1.48$^{b}$ | 6.08±1.40$^{b}$ | 5.11±1.55$^{c}$ | 8.11±0.85$^{a}$ |
| Aroma | 6.19±1.33$^{b}$ | 6.22±1.62$^{ab}$ | 5.11±2.08$^{c}$ | 7.22±1.49$^{a}$ |
| Crunchiness | 6.19±1.53$^{ab}$ | 6.39±1.84$^{ab}$ | 5.75±1.84$^{b}$ | 6.92±1.13$^{a}$ |
| Appearance | 6.61±1.40$^{b}$ | 6.17±1.50$^{bc}$ | 5.61±1.55$^{c}$ | 7.89±1.04$^{a}$ |
| **Overall acceptability** | **6.14±1.46$^{b}$** | **6.39±1.57$^{b}$** | **4.75±2.06$^{c}$** | **7.92±1.15$^{a}$** |

Results is mean ± SD. Mean values with different superscripts along each row differ significantly ($p<0.05$). Control* is plain wheat crackers (0 % insect flour)

Table 3. Effect of inclusion level of termite flour on sensory acceptability of enriched crackers

| | Insect flour inclusion level | | |
|---|---|---|---|
| Sensory attributes | 5% inclusion | 10% inclusion | 15% inclusion |
| Appearance/color | 7.33 ± 1.24$^{a}$ | 6.53 ± 1.41$^{b}$ | 5.97± 1.69$^{c}$ |
| Flavor | 6.87 ± 1.11$^{a}$ | 5.93 ± 1.34$^{b}$ | 6.27 ± 1.66$^{ab}$ |
| Taste | 7.07 ± 1.34$^{a}$ | 6.07 ± 1.41$^{b}$ | 6.37 ± 1.59$^{ab}$ |
| Crunchiness | 7.53 ± 1.07$^{a}$ | 7.03 ± 1.27$^{a}$ | 7.53 ± 1.28$^{a}$ |
| Texture | 6.93 ± 1.14$^{a}$ | 6.73 ± 1.26$^{a}$ | 7.33 ± 1.21$^{a}$ |
| **Overall acceptability** | **7.30 ± 0.70$^{a}$** | **6.67 ± 1.06$^{b}$** | **6.80 ± 1.35$^{ab}$** |

Results is mean ± standard deviation. Mean value with different superscripts along each row differ significantly ($p<0.05$)

## Discussion

*Sensory characteristics of enriched crackers and the control*

Sensory qualities and overall acceptability scores of termite enriched crackers were above 5. The termite crackers were generally accepted by consumers. Cricket enriched crackers scored below 5 and was considered un acceptable to consumers. Winged termite crackers was most preferred; it ranked highly in most sensory attributes; flavor, taste, aroma, crunchiness, and texture; having no difference from the control. High sensory acceptability was attributed to the fat content of crackers. Winged termites are rich in fat (Ekpo and Onigbinde, 2007; Raksakantong *et al*., 2010; Igwe, 2011; Kinyuru *et al*., 2013). Fats do absorb, preserve and contribute specific flavors to foods (O'brien *et al.,* 2010). Fats also impart characteristic softness and smoothness on food texture (Rajah, 2014; Rios *et al*., 2014). Similar findings were reported for cream and butter crackers (Owusu *et al*., 2011). Crackers enriched with cricket flour scored least in all the sensory attributes investigated, perhaps as a result of the flour imparting a characteristic cricket aroma/ flavor and dark green color onto crackers. Aroma and color of flours are shown to affect acceptability of composite crackers substantially (Noor and Komathi, 2009; Han *et al*., 2010; Manaois *et al*., 2013).

Substituting wheat flour at 5, 10, and 15% with ground winged termites yielded acceptable crackers to consumers. Cracker at 5% substitution was most preferred (7.3); it ranked highly in color (7.33), flavor (6.87) and taste (7.07). sensory analysis of wheat buns substituted with 0%, 5%, 10% and 20% ground termite indicated that buns at 5% wheat substitution ranked highest in all the sensory attributes evaluated (Kinyuru *et al*., 2009). Color of crackers ranked low at 15% substitution (5.97). Decrease in acceptability of crackers color with increased proportion of winged termites is thought to be as a result of winged termite flour imparting a dark color on the crackers which possibly gave the panelist an impression of 'over-baked' product, thus affecting their likings. A Similar observation was made by Noor and Komathi (2009) for mango peels incorporated in cracker formulation.

Protein and energy content of crackers increased with proportions of winged termite's flour in the formulation. Winged termites are rich in protein and fats (Oyarzun *et al*., 1996; Bukkens, 1997; Ramous Elorduy *et al*., 1997; Ekop and Onigbinde, 2007). Fat is a dense source of energy (O'brien, 2010; Rajah, 2014; Rios *et al*., 2014). Protein and energy at 5% substitution was within the range (11-15 mg/100g) and (375-518 kcal/100g) reported for fish crackers; Neivia et al. (2011) and Nurul *et al.* (2009) respectively. Protein in the enriched crackers (13.05-16.05 g/100g) was superior (7.87-9.92 g/100) to non-enriched crackers (Norhayati *et al*., 2015). While the energy value (438.05-476.75 kcal/100g) was in the range (406.57-533.30 kcal/100g) provided for other types of crackers (Tangkanakul *et al*., 1999).

Iron and Zinc increased from 5.35 to 9.35 mg and Zn from 4.15 to 5.50 mg/ 100 g at 5% and 15% respectively. These values were higher than reported for most crackers (Norhayati *et al*., 2015). This wass attributed to the high quantities of essential minerals in termites. (Christensen *et al*., 2006). This product is appropriate for consumption to people of all ages to supplement on the nutrient intake from the conventional foods. However, Ayieko *et al*. (2010) recommended insect crackers as a better snack than

Table 4. Effect of inclusion level on nutrient profile of crackers and contribution to Recommended Dietary Intake of preschool children

| | | Insect flour incorporation level and % contribution to RDI* | | | |
|---|---|---|---|---|---|
| Parameter (per 100 g) | RDI/ day[a] | 5 % | % RDI* | 10 % | 15 % |
| Energy(kcal) | 1200 | 438.05 ± 0.07[c] | (9.13) | 457.35 ± 0.07[b] | 476.75 ± 0.07[a] |
| Protein (g) | 13 | 13.05 ± 0.07[c] | (25.06) | 14.45 ± 0.07[b] | 16.05 ± 0.07[a] |
| Iron (mg) | 7 | 5.35 ± 0.07[c] | (19.11) | 7.35 ± 0.21[b] | 9.35 ± 0.21[a] |
| Zinc (mg) | 3 | 4.15 ± 0.07[c] | (34.58) | 4.85 ±0.07[b] | 5.50 ± 0.14[a] |

Results is mean ± SD. Values with different superscripts along each row differ significantly ($p<0.05$). Values in bracket are the percentage contribution of 25 g of crackers enriched with 5% winged termites to DRIs of pre-school children. a Dietary Reference Intakes (DRIs) (Otten *et al.*, 2006).

regular biscuits for children. Consumption of 25 g of crackers enriched with 5% winged termites, contributes 19.10% and 34.58% of the Recommended Dietary Intake (RDI) of iron and zinc in pre-school children (Otten *et al.*, 2006). This product is expected to be safe for consumption as crackers have low water activity and studies by Saritha and Patterson (2012) indicated very low total plate count.

Processing temperatures of winged termites affected the nutrient quality of the resultant crackers. In vitro protein digestibility decreased from 26.23% at 90°C to 20.56% at 150°C. Depending on the processing conditions, heat processing may reduce or increase protein digestibility. Exposure to denaturation temperatures may increase digestibility of the native proteins by unfolding of the polypeptides chains and rendering the protein more digestible (Opstvedt *et al*., 2003). However, Oria *et al*. (1995) reported that exposure of proteins to dry heat, may cause a reduction in protein digestibility due to the formation of the di sulphide bonds in the protein. Roasting conditions (high temperature and low moisture content) favors Maillard reaction which leads to a decrease both in protein digestibility and availability of amino acids involved (Bjorck and Asp 1983). This perhaps explains the reduction in digestibility of crackers.

Kinyuru *et al*. (2010) studied the influence of processing methods on termites and grasshoppers and reported that there was no significant change in digestibility of fresh, toasted, toasted dried, and fresh dried termite samples. While a significant decrease in digestibility of grasshopper samples was observed on toasting and drying. According to El Hassan *et al.* (2008) toasting and boiling of tree locust increased tannin and phytate content in the flour, which could explain the reduction in the protein digestibility with

Table 5. Effect of processing temperature of termites on nutrient qualities of enriched crackers

| | processing temperature and time | | |
|---|---|---|---|
| Parameters | 90 °C /10 min | 120 °C /10 min | 150 °C/ 10 min |
| Protein digestibility | 26. 23 ± 0.18[a] | 20.35 ± 0.91[b] | 20.56 ± 0.88[b] |
| Energy value | 488.29 ± 0.55[c] | 497.56 ± 0.35[b] | 519.13 ± 0.54[a] |
| Fe solubility | 42.26 ± 3.02[a] | 42.73 ± 1.44[a] | 20.79 ± 0.47[b] |
| Zn solubility | 27.63 ± 1.41[a] | 21.97 ± 1.15[b] | 18.32 ± 1.32[b] |

Results is mean ± SD. Values with different superscripts along each row differ significantly ($p<0.05$).

the increase in the processing temperatures.

Generally, *in vitro* protein digestibility of the products was quite low perhaps as a result of the methods of analysis used. In vitro protein digestibility of biscuits, cookies and muffins ranged from 79-92% for studies where a three enzyme (trypsin, chymotrypsin and peptidase) one-step digestion was used, where as in the same products, the digestibility ranged from 34-49% where a two enzyme (pepsin and pancreatin) two-step digestion was used (Abdel-Aal, 2008). The higher protein digestibility obtained by the three enzyme digestion is expected as explained by the synergic effect of the three proteolytic enzymes. However, the two enzyme digestion method was more reliable than the multiple enzymes, one-step digestion in determining differences in protein digestibility among the products, probably due to the lower enzyme activity and complexity of the food matrices. In the current study, a single enzyme (pepsin) digestion was used; which probably explains the lower values.

Energy value of crackers increased with increase in processing temperatures of termites; probably due to effect of temperature on the food components. Energy value in food is a function of protein, fat and carbohydrate (Ademulegun and Koleosho 2009). This may change according to the changes in the food components as a result of heat treatment. These values were higher than reported for biscuits supplemented with full fat soy four (Shrestha and Noomhorm, 2002). At 150°C (519.13 kcal/100 g), values were comparable to 518.07 kcal/100g reported for fried fish crackers (Nevia *et al*., 2011).

Increased processing temperature of winged termites led to reduction in iron and Zinc solubility of the resultant crackers, most likely due to formation of complexes with other food constituents as well as anti-nutrients. Anti-nutritional factors like phytates form a complex with minerals like Fe and Zn which is insoluble at the physiological pH of the intestine

(Ikeda *et al*., 1986; Frontela *et al*., 2011). Phytates significantly affected bioavailability of trace elements from soy weaning formulas containing cereals in a study by Lonnerdal *et al.* (1994). Adeduntan (2005) reported phytates concentration of 112 mg/100g and tannin content of 25 mg/100g of winged termites. While El Hassan *et al*. (2008) reported increased content of phytates and tannin in tree locust on frying and boiling. Fe solubility for crackers enriched with winged termites processed at 90$^{o}$C (42.26%) and 120$^{o}$C (42.73%) was twice the value (20.45%) reported for wheat bread, while Zinc solubility at 90$^{o}$C (27.63 %) and 120$^{o}$C (21.97%) was comparable to 26.6% reported for white wheat bread by Frontela *et al*. (2011). Insect wheat crackers could be consumed along with other foods rich in Zn and Fe to enhance its benefits.

## Conclusion

Substituting wheat flour with 5% termite flour processed at 90°C/ 10 minutes yielded enriched crackers with good sensory acceptability and nutrient quality. Termites are a valuable resource to be assimilated in the fast growing bakery industry with a potential of enriching the wheat flour which is a common ingredient in the bakery industry to produce diverse nutritious, convenient and well acceptable insect products. The use of termite flour to enrich locally available food ingredients like tapioca in the bakery industry could also increase the diversity of insect products and reduce the cost of production. Further analysis on the product is needed to comprehend its shelf life.

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