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Effects of drying on the nutritional, sensory and microbiological quality of edible stinkbug *(Encosternum delgorguei)*

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A R T I C L E I N F O

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A B S T R A C T

Entomophagy has recently gained attention as a potential solution to the problems of food and nutritional security. One example is the consumption of edible stinkbug. Different drying techniques may affect the nutritional, microbiological and sensory properties of the edible stinkbugs. Thus, the study assessed the effects of toasting, microwave, oven and sun drying on the nutritional composition, microbiological quality and sensory attributes of processed edible stinkbugs. Drying significantly ($p < 0.05$) increased the crude protein and fat content of the edible stink bugs with the highest values being recorded for the toasted samples (66.65 & 37.17% respectively). Highest Ca, K, Zn, Mg, Fe and P values were recorded after microwave drying. Reduction of 2.94 and 2.99 log cycles of the total viable count (TVC) was observed in oven and microwave dried edible stinkbugs. Toasting and microwave drying eliminated the yeasts and moulds, *Enterobacteriaceae* and lactic acid bacteria (LAB) in edible stinkbugs. The appearance, aroma, taste, texture and overall acceptability scores were in the same order for toasted > oven dried > microwave dried > sun dried edible stinkbugs. Toasting, oven and microwave drying can be used for processing of edible stinkbugs.

1. Introduction

Globally, food insecurity and subsequently malnutrition continues to be a public health concern [1]. Malnutrition statistics for 2020 estimated that more than 2 billion people were suffering from micronutrient deficiencies, 462 million adults were underweight, 149,2 million children under 5 were stunted and 45.4 million were wasted. Of the 770 million people reported to be undernourished in 2020, Africa had the highest prevalence (21%) [2]. Some of the major causes of these problems include the impacts of climate change induced shocks (droughts and floods), man-made challenges (increased food prices, disparity in food distribution) and the COVID-19 pandemic [2]. The projected population growth to 9.8 billion in 2050 [3] may increase this prevalence of food insecurity and malnutrition. Hence, increase of research into alternative nutritious and sustainable sources of food. Insect consumption also known as entomophagy has gained attention as a potential source of valuable nutrients; high content of proteins, unsaturated fatty acids and minerals [4].

Edible stinkbug (*Encosternum delegorguei*) has been reported to play a role towards attainment of food and nutritional security in rural communities in subtropical woodland and bushveld in Zimbabwe [5]. The insect is a good source of protein (37.3%), fat

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(50.65%) and some minerals (Ca- 91 mg/100 g, Fe- 20.2 mg/100 g and Zn- 46 mg/100 g) [6]. Unsaturated fatty acids (e.g. linoleic acid, palmetoic acid, oleic acid) make up to 70% of the detected fatty acids in edible stinkbug [7]. Harvesters of edible stink bugs mainly rely on harvesting them from the wild between May and August [5]. Processing of the harvested edible stinkbugs involves vigorous stirring of the insects in water for 5 min at approximately 37 °C, followed by draining the water and finally rinsing using cold water. The insects are then roasted to golden brown in clay pots, salted, sun dried and packaged for storage [8]. The presence of black thoraces and abdomen is used for the identification of not well prepared edible stinkbugs, which are removed from the well processed ones [9]. Apart from reducing the defense chemical present in edible stinkbugs and making them more palatable, processing also increases the shelf life from 2 days to 6 months although samples have been reported to have a moudly taste [8]. Dzerefos et al. [8] highlighted that insects with a high fat content do not completely dry and susceptible to mould attack. Thus, there is need for improved processing techniques that can both increase the shelf life and at the same time maintain the palatability of the edible stinkbug.

Other innovative technologies for increasing the shelf life and microbiological quality, reducing the rancidity, and improving the colour and texture of edible insects are freeze drying, microwave-assisted drying and oven drying [10]. For example, oven-drying, spray-drying crickets, and microwave-drying mealworm showed that these different drying techniques result in different microbial loads, nutritional, and sensory outcomes [11–13]. Kroncke et al. [12] reported the formation of a range of volatiles (aldehydes, ketones and alcohols) from drying of mealworms. Such volatiles are responsible for flavouring characteristics of the dried product. A comparison on different drying methods by Mishyna et al. [14] showed that microwave drying of locusts (*Locusta migratoria manilensis*) and silkworms (*Bombyx mori*) resulted in more typical Maillard reaction products as well as lipid oxidation aldehydes compared oven drying. Microwave drying improved the mineral content and lowered the microbial load compared to hot air oven drying [15]. Although, several studies have been done on the various drying technologies use on different insects the effects cannot be generalised for all insects especially considering diversity in the processing effects, insect species and matrices. Furthermore, studies have mostly reported the nutritional composition of the edible stinkbug with limited information on processing effects. Therefore, the aim of this study is to determine the effects of microwave drying, oven drying, toasting and sun drying on the nutritional content, microbiological quality and sensory attributes of edible stinkbugs.

2. Methodology

2.1. Sample collection

Edible stinkbugs were obtained from the Jiri Forest (Fig. 1), (approximately 20°2′ 55″ S 31° 43′ 36″ E) in the Nerumedzo area of Bikita District, Masvingo Province, South-eastern Zimbabwe, between 2020 and 2021. The knock down approach from tree branches was used to dislodge the bugs onto a flat sheet. The bugs were immediately removed from the sheet and placed in a perforated plastic bags to keep them alive and transported to the Food Science Laboratory at Chinhoyi University of Technology. The insects were killed in warm water, rinsed, packaged in polythene bags and stored at −20 °C awaiting analysis.

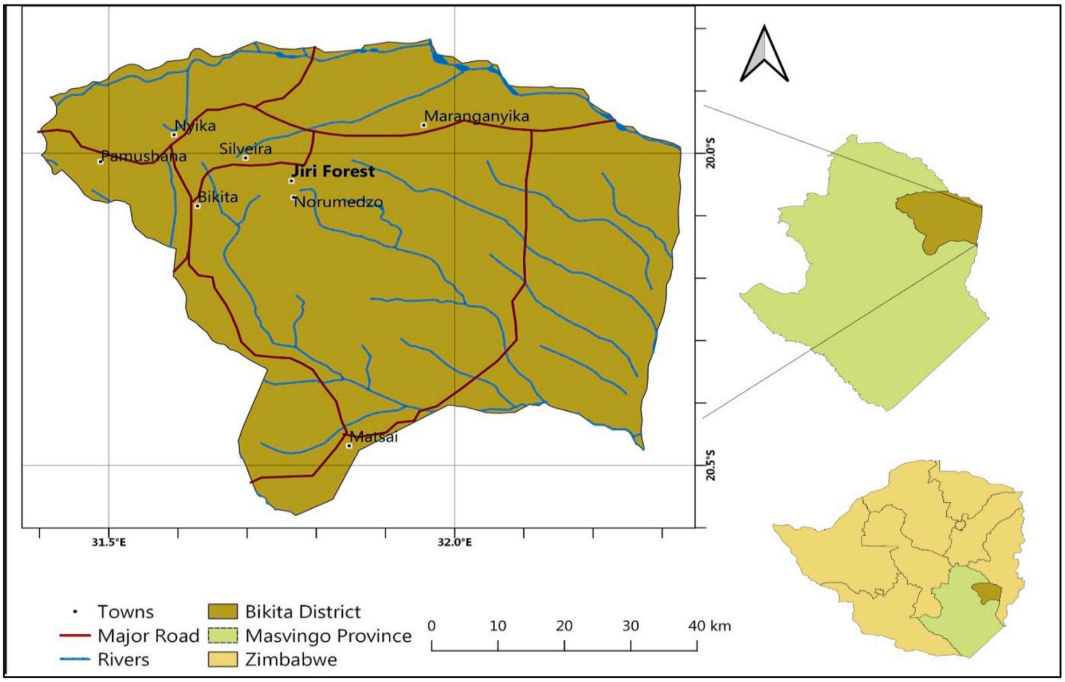

Fig. 1. Map showing the area the Edible stinkbugs were collected.

2.2. Sample processing

Edible stinkbugs samples were processed by microwave drying, oven drying, toasting and sun drying. For oven drying 300 g of the stinkbugs were evenly spread in an aluminium tray and dried to constant weight at 60 °C in an oven (Scientific, South Africa) following the method by Fombong et al. [16]. Microwave drying was done as previously described by Bawa, (2020) with some modifications, briefly 300 g of stinkbugs were placed in a ceramic bowel and placed in a domestic microwave (Defy, South Africa). Samples were dried at 1-min regular intervals for the first 3 min and then continuously for 1 min and stopped for 4 min until a constant weight was achieved. Toasting was achieved by placing a clean dry stainless steel pan on a hot plate and heating to about 150 °C as previously described Nyangena et al. [17]. Raw insects (300 g) were then placed on the hot pan and without addition of cooking oil fried for 5 min, with regular turning using a wooden cooking stick to avoid sticking or burning.

The samples were left to cool to room temperature and were ground in a domestic 4 speed blender (AE-099, China) at speed 3. Samples were then analysed for nutritional content, microbiological quality and sensory quality.

2.3. Methods

2.3.1. Proximate composition

Moisture content was analysed using the forced air oven (Scientific, South Africa) at 105 °C for 24 h according to Vandeweyer et al. [13]. Ash content was determined using a muffle furnace at 550 °C for 5 h as described by Zielinska et al. [18]. Crude protein content was determined using the Kjeldahl method using Velp Scientifica digestion and distillation (UDK 149) system (Velp Scientifica, Italy). Protein content was calculated using 5.6 as the conversion factor. Crude fat content was obtained using the soxhlet method described by Nielsen [19]. Petroleum ether was used as the solvent, it was then removed using a rotary evaporator (ROVA-N26, Spain) at 50 °C. Crude fibre content was analysed following a method by Santibala et al. [20]. Each of the ground samples (2.0 g) (F1) was placed into a 300 ml conical flask, to which 200 ml of 0.128 M H_2SO_4 was then added and boiled for 30 min. Thereafter, it was filtered through Whatman filter paper number 1 followed by washing three times with hot water (80 °C). The residue was placed back into the conical flask. Following the addition of 200 ml of 0.223 M NaOH, the sample was heated for 30 min before being filtered through whatman filter paper number 1. The residue was then washed with 25 ml of 0.128 M H_2SO_4, three 50 ml portions of water and 25 ml of ethanol. Thereafter, the residue was transferred into a pre-weighed crucible (F2), dried at 130 °C for 2 h, cooled in a desiccator and weighed (F3). The samples were then ignited for 30 min at 600 °C, cooled in a desiccator and reweighed (F4). The percentage crude fibre was calculated as shown in equation (1):

$$\text{Crude fibre }(\%) = \frac{mi}{\text{mtot}} \text{x } 100 \tag{1}$$

Where m_i – mass (g) of residue (F_3–F_2) minus mass of ash (F_4–F_2) and m_{tot} – is the total mass (g) of edible stinkbug sample (F_1).

2.3.2. Mineral content

The wet ashing method was used for the determination of minerals as described by Akinyele & Shokunbi [21]. The minerals (Ca, K, Na, Mg, Cu, Fe and Zn) were determined using an atomic absorption spectrophotometer (PerkinElmer PinAAcle 900 F). Phosphorus was determined following a method described by Jastrzębska et al. [22] by reading the absorbance at 730 nm on a UV-VIS spectrophotometer (PerkinElmer Lambda 365).

2.3.3. Determination of microbiological quality

Samples for the determination of the total viable mesophilic counts, *Enterobacteriaceae*, Lactic acid bacteria, yeasts and moulds in dried samples were prepared using a method described by Caparros Megido et al. [23]. The total number of aerobic mesophilic count were determined by spreading 1 ml of the diluted samples on Plate Count Agar and incubating at 30 °C for 72 h. *Enterobacteriaceae* was plated on Violet Red Bile Glucose Medium and incubated at 37 °C for 24 h. Lactic acid bacteria were plated on de Man Rogosa Sharpe Medium and incubated at 30 °C for 72 h. Yeasts and moulds were determined by plating the samples on Oxytetracycline Glucose Agar, supplemented with oxytetracycline and incubation at 25 °C for 5 days.

2.3.4. Determination of sensory quality

A semi-trained panel of 50 people was used to evaluate the taste, texture, aroma, appearance and overall acceptability of the dried stinkbug samples. Informed consent was obtained from all the panellists. A nine-point hedonic scale was used to evaluate the appearance, aroma, taste, texture and overall acceptability. The scores were ranging from 1 to 7 (1 = strongly disliked and 9 = strongly like) [24].

2.4. Statistical analysis

Unless otherwise stated, all experiments were carried out in triplicate. Results were analysed and expressed as mean values with standard deviations. Analysis of variance (ANOVA) was used to analyse the significance of difference between treatments and Fischer's Least Significant Differences Test was used to compare means ($p < 0.05$ and $p < 0.01$).

2.5. Ethical consideration

The study was approved by the Ethical Review Committee of Jaramogi Oginga Odinga University of Science and Technology. Approval No: ERC 23/11/21–1.

3. Results and discussion

3.1. Nutritional content

The nutritional composition of the edible stinkbugs was significantly ($p < 0.05$) affected by the processing technique (Table 1). Processing resulted in the decrease of the moisture content of edible stinkbugs as shown in Table 1. Raw edible stinkbugs had the highest moisture content (43.84%). Microwave, oven and sun drying had the highest effect on the moisture content to values < 5%, while toasting had the least effect (15.09%). The low moisture content of sun dried, microwave dried and oven dried stinkbug shows that these drying methods can be used to prolong shelf life. Furthermore, such low moisture contents suggest that the processed edible stinkbugs can be stored at ambient temperature [13]. Ash content of the edible stink bugs differed significantly ($p < 0.05$) with each processing method. A significant decrease ($p < 0.05$) in the ash content was observed after toasting the edible stinkbugs. All the other processing techniques (microwave, oven and sun drying) resulted in a significant increase in the ash content ($p < 0.05$). Increase in the ash content is related to increase in the mineral levels.

The crude fat content (57.32–66.65%) was above the ranges (38.90–62.40%) reported in previous studies [7,9], the edible stinkbug is a good source of energy. Various factors; sex, reproduction stage, diet, season and habitat affect the fat content of the insect [25]. Crude protein content of the edible stinkbugs (27.94–33.30%) slightly below the ranges (31.30–43.30%) reported in previous studies [7,9]. Differences in the protein content reported in the various studies could be due to effect of location (where the edible stink bugs where collected), vegetation type (insect food) and season. Also in this study a lower conversion factor of 5.6 was used for the calculations [26]. Ssepuuya et al. [27] reported a significant variation in protein content of *Ruspolia nitidula* due to geographical location and swarming season.

Processing also affected the crude protein and crude fat content of edible stinkbugs. Toasting, microwave drying and sun drying resulted in an in increase in both the crude protein and fat content, with the highest increase values being observed after toasting. However, sun drying led to a decrease in both the crude protein and fat content compared to raw edible stinkbugs. Selaledi and Mabelebele [28] reported a lower protein content in sun-dried yellow mealworm (*Tenebrio molitor* L.) as compared to the oven dried samples anticipated to have been influenced by the dry matter base of the samples. Other studies have reported a decrease in protein content during drying and this has been anticipated to be related to protein denaturation and/or browning reactions that uses part of the amino acids [29]. However, like in the present study microwave drying was reported by Wu and Mao [30] to result in an increase in protein content of grass carp fillets and some of these differences could be due to differences in the biological matrix.

Edible stinkbugs had a high crude fibre content ranging between (18.13–25.47%) within the ranges (14.80–22.00%) previously reported by Musundire [7]. Crude fibre content of edible stinkbugs was increased due to oven drying and sun drying while toasting and microwave drying resulted in a decrease in the crude fibre content. Oven drying achieved the highest fibre content (25.47%) while toasting (18.13%) led to the least fibre content. There was no significant difference due to the effects of toasting and microwave drying. Insects contain significant amounts of fibre, predominantly chitin and complex carbohydrates such as cellulose and lignin that might be present in the insect's gut [16]. Fombong et al. [16] highlights that chitin is the major component of the insect cuticle and is covalently bound to catechol compounds and sclerotin proteins.

3.2. Mineral composition

The mineral composition of the dried edible stinkbugs was within ranges found in the previous studies [6,7]. Edible stinkbug is a source of several micronutrients including Fe and Zn (Table 2). All the drying techniques increased the mineral composition (Ca, K, Zn, Mg, Fe and P) of the edible stinkbugs, with the highest values being recorded after microwave drying. However, Cu was reduced by oven drying and sun drying whilst all the other processing techniques except toasting reduced the Na levels. Higher values ($p < 0.05$) of Ca, Mg, Cu, Na and P were recorded in oven-dried yellow mealworm (*Tenebrio molitor* L.) as compared to the sun-dried samples [28]. In the same study, sun drying of yellow mealworms resulted in higher Fe, Mn, Zn and K compared to oven drying [28]. Similar to the

Table 1
Effect of processing technique on the proximate composition of edible stinkbug.

Processing technique	Moisture content (g/100 g)	Ash (g/100 g DM)	Crude Fat (g/100 g DM)	Crude protein (g/100 g DM)	Crude Fibre (g/100 g DM)
Raw	43.84 ± 0.84^{c}	0.67 ± 0.03^{b}	57.32 ± 0.51^{b}	29.95 ± 0.16 b	21.01 ± 0.60^{b}
Toasted	15.09 ± 0.22^{b}	0.73 ± 0.07^{a}	66.65 ± 0.42^{d}	33.30 ± 0.93 d	18.13 ± 0.44^{a}
Microwave	3.13 ± 0.02^{a}	1.20 ± 0.05^{d}	59.33 ± 0.31^{c}	32.01 ± 0.10c	18.44 ± 0.28^{a}
Oven	3.25 ± 0.08^{a}	2.02 ± 0.02^{e}	60.33 ± 0.64^{c}	31.88 ± 0.12c	25.47 ± 0.21^{d}
Sun	3.43 ± 0.02^{a}	1.52 ± 0.06^{c}	50.96 ± 0.33^{a}	27.94 ± 0.21a	23.27 ± 0.36^{c}

DM = mass of dried edible stinkbugs, Values are mean ± SD (n = 3); different superscripts indicate significant differences ($p < 0.01$) within the various processing techniques.

Table 2
Effect of processing technique on the mineral composition of edible stinkbug.

Processing technique	Ca (mg/100 g)	K (mg/100 g)	Cu (mg/100 g)	Zn (mg/100 g)	Na (mg/100 g)	Mg (mg/100 g)	Fe (mg/100 g)	P (mg/100 g)
Raw	30 ± 1.74a	170 ± 2.38a	5.60 ± 0.01a	2.11 ± 0.02a	10 ± 0.64a	60 ± 0.34a	10.90 ± 0.24a	49 ± 1.19 ab
Toasted	60 ± 0.35 d	250 ± 1.77 b	6.02 ± 0.21a	2.23 ± 0.01 b	20 ± 0.16 b	80 ± 2.18 b	19.98 ± 1.34 d	61 ± 3.22c
Microwave	70 ± 0.58e	290 ± 3.36 d	8.15 ± 0.48 b	5.13 ± 0.10 d	10 ± 0.78a	100 ± 1.24 d	14.79 ± 0.53c	103 ± 1.64 d
Oven	40 ± 0.87 b	260 ± 0.69c	5.35 ± 0.02a	3.49 ± 0.32c	10 ± 0.47a	90 ± 0.89c	12.39 ± 0.12 ab	51 ± 0.45 b
Sun	50 ± 0.58c	260 ± 0.33c	5.39 ± 0.01a	3.54 ± 0.22c	10 ± 0.82a	90 ± 1.83c	13.61 ± 0.06bc	46 ± 0.32a

Values are mean ± SD (n = 3); different superscripts indicate significant differences ($p < 0.01$) within the various processing techniques.

present study higher mineral values have been reported also for microwave dried crickets than the oven dried samples [15]. This could be attributed to the long time that is required to dry food products in oven drying compared to during microwave drying [31] and the product degradation associated with conventional drying [32].

The RDI for Fe and Zn in children age between 4 and 13 years ranges between 8 and 10 mg/d and 5 and 8 mg/d respectively [33], suggesting that the edible stinkbug is a good source of Fe and is able to provide 50% of the Zn requirements. Fe in a variety of red meats ranges between 1.1 and 3.3 mg/100 g [34], hence the dried edible stinkbugs is a good source of Fe. Consumption of dried edible stinkbugs could assist in reducing the prevalence of iron and zinc deficiencies, proven to be a public health burden especially in African children [35].

3.3. Microbiological quality of processed edible stinkbugs

The various processing techniques caused a significant (*$p < 0.01$*) reduction on the total viable count (TVC) in edible stinkbugs (Table 3). The highest TVC count (4.57 Log CFU/g) was recorded in the raw edible stinkbug samples, The TVC counts in the raw and processed edible stinkbugs were within the allowable limit in edible insects. The limit of TVC's in edible insects has been proposed to be at least the same as it is for fresh minced meat [23]. According to the Commission of the European Communities the specifications of TVC for fresh minced meat are a lower limit of 5.7 Log cfu/g and an upper limit of 6.7 log cfu/g [36].

Oven and microwave drying of the edible stinkbugs resulted in the most reduction of 2.94 and 2.99 log cycles respectively of the TVC. The least reduction was observed in the toasted and sun-dried edible stinkbugs. Bawa et al. [15] also observed a reduction in Total Aerobic Count of oven and microwave dried house cricket *(Acheta domesticus*). In a study by Nyangena et al. [17] on comparing the effect of toasting and oven drying on *A. domesticus, H. illucens, Spodoptera littoralis and R. differensis.* Results contrary to those observed in the present study were recorded. An important reduction was observed in the TVC after use of toasting however oven drying could not guarantee the same results [17]. These differences could be due to the interaction effect of insect species and the processing method reported to be significant for the destruction of the TVC [17].

The raw edible stinkbug sample had the highest levels of *Enterobacteriaceae* (3.46 log cfu/g) and LAB (3.04 log cfu/g) (Table 3). *Enterobacteriaceae* category consists of bacteria such as coliforms, *Salmonella*, Shigella and *Escherichia coli*, hence this may indicate faecal coliforms from unhygienic environments, soil or poor handling [37]. All the other processing techniques (toasting, microwave and oven drying) except for sun drying destroyed both the *Enterobacteriaceae* and LAB. Similar results were reported in a study by Ng'ang'an et al. [38] who reported that *Enterobacteriaceae* and LAB were completely eliminated or reduced to a level below the detection limit upon toasting of *R. differens*. This is because these groups of bacteria are heat sensitive [39]. Hence also supporting their presence in the sun-dried samples, as the sun drying temperature ranged between 25 and 30 °C. *E. coli*, coliforms, and *Salmonella* were observed to be present on thermally processed and dried insects, for instance, on roasted (5 min) and sun-dried B. alcinoe [40], and boiled (30 min), sun-dried grasshoppers [41]. However, although they were detected *Enterobacteriaceae* levels in sun dried edible stinkbugs were below the expected limits reported for total coliforms less than 10^3 cfu/g (3 log cfu/g) in foodstuffs that require further cooking (>70 °C) [42]. Nyangena et al. [17] reported that oven-drying lowered the Lac + bacteria contamination by greater margin of 4.6–5.3 log cycles to acceptable limits in *H. illucens, A. domesticus* and *R. differens* whilst toasting totally eliminated them. In another

Table 3
Effect of processing technique on the microbial quality of edible stinkbug.

Processing technique	TVC (log cfu/g)	LAB (log cfu/g)	Enterobacteriaceae (log cfu/g)	Yeasts and moulds (log cfu/g)
Raw	4.57 ± 0.32c	3.04 ± 0.12c	3.46 ± 0.22c	3.24 ± 0.21 d
Toasted	2.52 ± 0.21 b	0.00 ± 0.00a	0.00 ± 0.00a	0.00 ± 0.00a
Microwave	1.58 ± 0.19a	0.00 ± 0.00a	0.00 ± 0.00a	0.00 ± 0.00a
Oven	1.63 ± 0.15a	0.00 ± 0.00a	0.00 ± 0.00a	1.37 ± 0.02 b
Sun	2.78 ± 0.06 b	2.33 ± 0.04 b	2.25 ± 0.00 b	2.46 ± 0.14c

Values are mean ± SD (n = 3); different superscripts indicate significant differences ($p < 0.01$) within the various processing technique.

study, Klunder et al. [39] reported that roasting of Mealworm larvae (*Tenebrio molitor)* decreased *Enterobacteriaceae* from 6.8 to 2.2 log cfu/g, however the study suggested that a combination of blanching the insects in boiling water and roasting is able to eliminate the *Enterobacteriaceae.* A decrease of more than 6 log cycles (from 8.01 to <1.63 log cfu/g) was recorded from the drying at 110 °C for 3 h of cricket (*A domesticus*) [43].

The presence of yeasts and moulds has been reported to cause spoilage in food products with a low water activity including dried edible insects [44]. Unprocessed edible stinkbug had the highest yeast and moulds levels of 3.24 log cfu/g (Table 3). The microbial limits of yeasts and moulds in dried edible insects is 5 log cfu/g [13]. Sun and oven drying resulted in a significant decrease in the yeasts and moulds in edible stinkbugs whilst toasting and microwave drying eliminated them. Nyangena et al. [17] also reported total elimination of yeasts and moulds in toasted *H. illucens A. domesticus R. differens S. littoralis*. However, in the study oven dried *H. illucens A. domesticus R. differens S. littoralis* had yeasts and moulds although a significant reduction was observed from the raw samples. Such differences could be due to differences in the insect species and matrix and their interaction with the processing method [17].

Overally, the various processing techniques resulted in a decrease in the microbial loads or elimination of some of the microbes. Drying of edible insects reduces the moisture content and water activity, thus slowing down microbial growth, chemical and enzymatic reactions subsequently increasing the product's shelf life [45]. Wynants et al. [46] also reported that decrease of the initial microbial load is due to exposure to heat which reduces microbial growth and contamination. Differences observed in the microbial load for each processing technique could be attributed to the exposed temperatures. Most bacterial species are destroyed at temperatures beyond 65 °C [1]. According to Grabowski and Klein [11] variations in microbial counts are strongly dependant on the insect species and treatment specific patterns and conditions.

3.4. Effect of drying techniques on the sensory properties of edible stinkbugs

The sensory properties of the edible stinkbugs were influenced by the processing method (Fig. 2). Highest scores for the evaluated sensory parameters that is appearance, aroma, taste, texture and overall acceptability were in the same order for toasted > oven dried > microwave dried > sun dried edible stinkbugs. Sensory properties of dried products are altered through the formation of volatile compounds occurring during drying [47]. Nofer et al. [48] reported that, drying of *Boletus edulis* led to quantitative variations in major volatiles, as well as, appearance, flavour, and texture, depending on the drying method. Toasting of edible stink bugs changes their colour from green to golden brown. According to Pokorny and Sakurai [49] such a colour compounds are as a result of aldehydes and lipid oxidation products reacting with the amino groups of proteins and free amino acids. Lipid thermo-oxidation had an impact on the aroma and colour of boiled and oven roasted grasshopper (*Ruspolia differens*) [50].

4. Conclusion

Different drying methods (toasting, microwave, oven and sun drying) had a significant ($p < 0.05$) effect on the nutritional

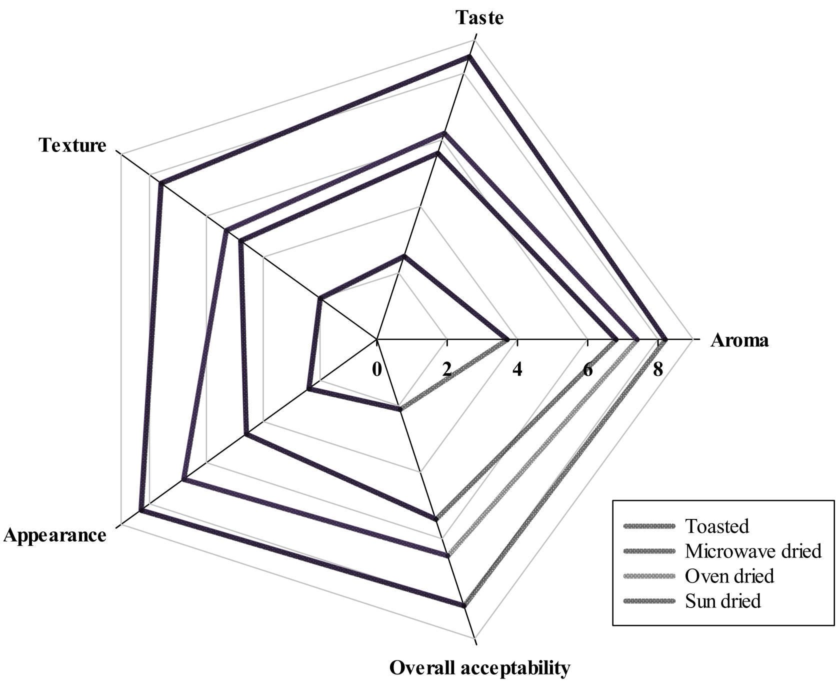

Fig. 2. Effect of processing technique on the sensory properties of edible stinkbug.

composition, microbiological quality and sensory attributes of processed edible stinkbugs. Toasting, microwave and oven drying increased the crude protein and fat content of the edible stink bugs. The highest crude fat (66.65%) and protein content (37.17%) were observed in toasted edible stinkbugs. Ca, K, Zn, Mg, Fe and P increased due to drying with the highest values being observed after microwave drying. Processed edible stinkbugs had improved microbial quality thus considered safe for human consumption. Toasted edible stinkbugs had better appearance, aroma, taste, texture and overall acceptability compared to oven dried, microwave dried and lastly sun-dried samples. Toasting, oven and microwave drying can be used for processing of edible stinkbugs. Future studies should determine the effect of these drying methods on shelf-life of edible stinkbugs in various packaged materials.

Ethics statement

The study was approved by the Ethical Review Committee of Jaramogi Oginga Odinga University of Science and Technology. Approval No: ERC 23/11/21–1. Informed consent was obtained from all the panellists.

Author contribution statement

Melania Dandadzi: Conceived and designed the experiments; Performed the experiments; Analysed and interpreted the data; Wrote the paper.

Robert Musundire, Alice Muriithi, Ruth T. Ngadze: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Data availability statement

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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