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RESEARCH ARTICLE

Potential of a powdered Mopane worms-breakfast meal blend as a nutritious porridge for children in Zambia

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Abstract

In Zambia, the intake of animal-sourced proteins remains low in many households, despite their essential role in supporting physical growth, cognitive development in children, and overall health in adults. Among edible insects, Mopane worms are widely consumed and offer protein content comparable to conventional meats. However, there is limited research on incorporating Mopane worms into cereal-based foods such as porridge to enhance their nutritional value, and little is known about the nutritional composition and consumer acceptability of such products. This study investigated the nutritional attributes and consumer acceptance of porridge made from two Mopane worm, breakfast meal composite blends and one conventional breakfast meal. Mopane worms (variety *Mumpa kaseke*) were sourced from Muchinga Province and processed under clean, dry conditions. Two composite blends were formulated following World Food Programme super cereal guidelines: MB80 (80% breakfast meal and 20% Mopane worm powder) and MB75 (75% breakfast meal and 25% Mopane worm powder). The samples were analyzed in triplicate for proximate composition and mineral content (calcium, iron, and zinc) using AOAC (2005) methods. Consumer acceptability was also assessed for the three porridge types.

Results indicated that Mopane worm powder had a high protein content (55.60 ± 4.01%). The MB80 and MB75 composite blends contained 16.74 ± 1.98% and 19.04 ± 1.11% protein, respectively. MB75 had higher iron content (1.74 ± 0.74%) than MB80 (1.04 ± 0.19%), while MB80 had more zinc (0.57 ± 0.11%) than MB75 (0.41 ± 0.74%). Statistically significant differences ($p < 0.05$) were found in proximate and mineral composition across the three samples. Between MB80 and MB75, only moisture, ash, and crude fiber differed significantly. In terms of sensory attributes, consumer acceptability ratings for aroma, taste, and overall preference showed no significant differences ($p < 0.05$) among the three porridge types. Similarly, there were no significant differences between MB80 and MB75 in terms of consumer ratings for any attribute.

In conclusion, the inclusion of Mopane worm powder into breakfast meal significantly improved the nutritional content of porridge, especially in protein, fat, and fiber, while maintaining consumer acceptability. These findings highlight the potential of insect-based composite flours as a sustainable strategy to improve dietary protein intake and address malnutrition in low-income settings.

***Key words**: Breakfast meal, Composite blends, Mopani Worms, Zambia*

1.0 Introduction

Mopane worms (*Gonimbrasia belina)* are edible caterpillars of the Emperor Moth that are harvested from the forests of warmer parts of Southern Africa [1]. In Zambia, they are commonly called *ifishimu* and consumed locally as accompaniments during main meals or as a snack. Other edible insects include termites or *Inswa* (*Macrotermes falciger*) and *Shongonono* (*Ruspolia differens*) [2]. Entomophagy in Zambia is an established practice based on distinct names given to insects meant for human consumption whereas those not consumed are generally referred to as *Vidoyo* [3].

Studies indicate that the nutrient content of edible insects is comparable to conventional animal protein sources [4]. On the basis of such findings, a number of companies around the world now exist that supply insects for consumption as whole or processed powders [5]. Food powders are food materials that have been reduced to particulates [6]. Because of the benefits they present, the use of food powders and development of their related technologies has increased. Powders have been used as food ingredients to improve sensorial properties and nutritional value of other foods as Food-Based Fortificants [7]. Powders prepared from insects have been utilized in this way as well and have the potential of being added to cereal foods like maize flour.

Previous studies have shown that insects belonging to the family Saturniidae (to which Mopane worms belong) have high protein content. A study [8] reported protein content of insects in this family as ranging from 52 to 70 % dry weight (DW). Protein-rich foods and animal-sourced proteins in particular are critical for childhood physical and mental development. In spite of this, a report on affordability of protein rich foods in Zambia noted that intake of conventional protein from animal sources was relatively low for low income households [9].

In Zambia, foods of vegetable origin provided 95% of energy supply and more than 80% of protein and lipid supplies [10]. Such a contribution is insufficient in terms of protein availability and quality, and highly deficient in micronutrients. Therefore, there is need to look for alternative sources of other nutrient-rich foods to cater for the protein and micronutrient needs of the most vulnerable in the population including women and children. Use of food powders as ingredients has been shown to significantly improve nutritional value of other foods without necessitating drastic changes in dietary behavior [11].

Therefore, there is potential for these food resources to be utilized to enhance the nutritional profiles of cereal based powders and other products. This could encourage possible diversification of the consumption methods of Mopane worms and also enhance the nutritional value of breakfast meal as it is commonly used to prepare most porridges but usually lacks essential amino acids and other nutrients.

2.0 Materials and Methods

2.1. Procurement of samples

Mopane worms were purchased and received by 28th May, 2021 in whole dried form. They were sourced from Muchinga province in Zambia from a single supplier to limit potential variation due to source. The local name for the Mopane worms is *Mumpa kaseke*. Based on anecdotal evidence, the *Mumpa kaseke* variety is relatively more available during off season. Upon procurement, samples were stored under cool dry conditions in a clean, dry airtight plastic container. Industrially processed breakfast meal was obtained from a local retailer within Lusaka District and stored in an airtight plastic container.

2.2 Sample preparation and processing

Preparation and processing of Mopane worm samples was done according to standard methods [12]. Mopane worms were first dry cleaned and sorted manually using a winnowing basket to remove dust and other unwanted materials such as residual charcoal pieces from the smoking process. Dry cleaning was repeated three times to remove as much dirt as possible. Sample size reduction was then achieved by simple coning and quartering of the Mopane worms which were then washed in warm potable water and strained. The process was repeated three times and followed by drying at 55°C-65°C in a food dehydrator overnight until the worms could be easily crushed between the fingers. After drying, the samples were ground using a domestic blender and sieved with a simple stainless steel household sieve. The resulting powder was stored in plastic zip-lock bags for further laboratory and sensory analysis at the Food Chemistry Laboratory under the Department of Food Science and Human Nutrition at the University of Zambia.

2.3 Formulation of Mopane Worm-Breakfast meal (MBx) composite blends

Two formulations of the Mopane worm-breakfast meal composite blends were made based on the WFP (World Food Program) specifications for super cereal. Super cereal is a corn soy blend used to prepare porridge for both adults and children [13]. The ratio of maize meal to soybeans for super cereal is max 8 maize: min 2 soy. In the current investigation, two composite blends were thus prepared (MB_{80} and MB_{75}). The MB_{80} had 80% breakfast meal and 20% Mopane Powder, while the MB_{75} had 75% breakfast meal and 25% Mopane powder respectively. Mixing was achieved by intermittent blending of the specified amounts of each ingredient for 10 seconds at a time and repeated 3 times to ensure the composite blends were mixed as evenly as possible.

2.4 Nutritional profiling of Mopane worm powder and composite blends

Samples of Mopane worm powder and the two Mopane worm-breakfast meal blends (MB_{80} and MB_{75}) were analyzed in triplicate for proximate composition of crude moisture, crude fat, crude protein, total ash and crude fiber using AOAC official methods of 934.01, 920.39 (A), 984 (A – D), 942.05 and 978.10 respectively [14]. Total carbohydrate content was calculated by difference as described in equation 1:

Carbohydrate Content (%) = 100 – [crude protein content (%) + crude fat content (%) + total ash (%) + crudefibre (%) + crude moisture content (%)] (1)

The GBC Atomic Absorption Spectrophotometer was used to measure the contents of calcium while zinc and iron assayed using an Inductively Coupled Plasma Mass Spectrometry (ICP-MS) [15, 16].

2.5 Preparation of porridge from Mopane worm-breakfast meal composite flour

Porridge was prepared based on a method used in a study that evaluated the nutritional composition and consumer acceptance of legume fortified maize-meal porridge [17]. The formulations were prepared from the Department of Food Science and Human Nutrition Dietetics kitchen facilities. In summary, 200g of worm-breakfast meal composite flour were made into a paste with about 500ml of water in a large pot and mixed with about 1500ml of boiling hot water and cooked for 30 minutes while stirring with intermittently. The control sample of breakfast meal porridge was also prepared using the same procedure.

2.6 Consumer acceptance test

Sensory evaluation was conducted in two sessions for a total of 30 participants. It involved consumer acceptance testing of the two MB_x porridge blends and a blind coded control sample made from breakfast meal. Participants were instructed to assess the three samples for the following sensory attributes; appearance, texture (mouth feel), taste, aroma and overall acceptability based on the 9-point hedonic scale.

2.7 Statistical analysis

Proximate composition and selected mineral content were determined in triplicate for Mopane worm powder (MP) and the two Mopane worm- Breakfast meal blends (MB_{80} and MB_{75}). The results were presented as mean values ± standard deviation. Data were analyzed statistically using one-way analysis of variance (ANOVA) on a 5% level of significance. Significant differences amongst means were determined using the Duncan Multiple Range Test (DMRT). Means and standard deviations of each parameter for the respective sample are reported on. Results of the consumer acceptance test were recorded as ratings of acceptability on a 9-point hedonic scale for the breakfast meal control sample and two composite blends. Attributes considered were appearance, aroma, taste, texture and overall acceptability. Data was analyzed statistically using one-way analysis of variance (ANOVA) and significant differences amongst means were determined using the Duncan Multiple Range Test. Mean ratings and standard deviations of each attribute for the respective sample were determined. Frequencies of panelist demographics such as age, sex, income and frequency of edible insect consumption are documented.

3.0 RESULTS

3.1 Results of proximate composition (%) of Mopane worm powder (MP) and two Mopane worm-breakfast meal composite blends (MB_{80} and MB_{75})

Proximate composition (%) of Mopane worm powder (MP) and two Mopane worm-breakfast meal composite blends (MB_{80} and MB_{75}) are presented in Table 1. The two composite blends MB_{80} (20% MP) and MB_{75} (25% MP) both had higher moisture contents than the Mopane worm powder (9.23% and 8.27% respectively). The data shows that there are significant differences ($p<0.05$) in moisture content amongst the three samples. The results also reveal that there are significant differences amongst all three samples for mean ash content ($p<0.05$). The ash content of Mopane worm powder was significantly higher (7.67%) than that of the two composite blends.

The Mopane worm powder was found to have a higher fat content (10.86%) than the 80% and 75% breakfast meal blends which were not significantly different from each other (5.48% and 4.71% respectively). Data obtained for crude fat content of the samples showed significant differences between the Mopane worm powder and the composite blends. Results of the study revealed that Mopane powder had a protein content of 55.60±4.01 %, while the Mopane worm breakfast meal composites of MB_{80} (20% powder) and MB_{75} (25% powder) contained 16.74±1.98 % and 19.04±1.11 % protein respectively. Crude protein content was significantly different between the Mopane worm powder and the two composite blends ($p<0.05$). Data for crude fiber shows significant differences amongst all samples. Mopane worm powder had the highest crude fiber content (10.44%). Crude fiber content of the 75% blend was found to be significantly different (3.45%) and higher than that of the 80% blend (2.73%). The carbohydrate was found to be significantly different ($p<0.05$) between the Mopane worm powder and the

two composite blends. Mopane worm powder had a much lower carbohydrate content (13.81%) than the 80% and 75% breakfast meal blends (63.74% and 61.62% respectively).

Table 1: Proximate composition (%) of Mopane worm powder (MP) and two Mopane worm-breakfast meal composite blends (MB_{80} and MB_{75})

Nutritional parameters	Mopane worm powder (MP)	MB_{80} (20% MP)	MB_{75} (25%MP)	Sig
Moisture%	1.63±0.36	9.23±0.28	8.27±0.10	0.000
Ash% $_{DW}$	7.67±0.03	2.08±0.17	2.52±0.03	0.000
Crude fat% $_{DW}$	10.86±0.57	5.48±0.83	4.71±0.45	0.000
Crude protein% $_{DW}$	55.60±4.01	16.74±1.98	19.04±1.11	0.000
Crude fiber% $_{DW}$	10.44±0.24	2.73±0.29	3.85±0.74	0.000
Carbohydrates (non-fiber)% $_{DW}$	13.81±4.05	63.74±2.17	61.62±1.67	0.000
Gross Energy Kcal/100g	375.34±3.32	371.07±4.09	365.02±2.40	0.000

3.2 Content of selected minerals in Mopane worm powder (MP) and two Mopane worm-breakfast meal composite blends (MB_{80} and MB_{75})

Results of selected mineral content (mg/100g) of Mopane worm powder (MP) and two Mopane worm-breakfast meal composite blends (MB_{80} and MB_{75}) are presented in Table 2. It was found that the calcium content was not significantly different amongst samples of Mopane worm powder and the two breakfast meal blends. The iron and zinc contents of the Mopane worm powder were found to be significantly different from the 80% and 70% composite blends. Iron content of the Mopane worm powder (4.18mg/100g) was higher than that of the 80% and 70% composite blends (1.0mg/100g and 1.74mg/100g respectively). Zinc content was found to be significantly higher (mean value 1.8mg/100g) in Mopane worm powder compared to the 80% and 75% blends (mean values 0.41mg/100g and 0.57mg/100g respectively).

Table 2: Content of selected minerals in Mopane worm powder (MP), breakfast meal (BM) and two Mopane worm-breakfast meal composite blends (MB_{80} and MB_{75})

Nutritional parameters	Mopane worm powder (MP)	MB80 (20% MP)	MB75 (25%MP)	Sig
Calcium mg/100g DW	1100±0.10	1000±0.04	1090±0.05	0.187
Iron mg/100g DW	4.18±2.36	1.04±0.19	1.74±0.76	0.080
Zinc mg/100g DW	1.81±0.20	0.41±0.74	0.57±0.11	0.000

3.3 Consumer acceptance of composite blends

Socio-demographics of respondents with respect to age, sex and frequency of general insect consumption are shown in Figures 1, 2 and 3, respectively.

A consumer acceptance test was conducted in two sessions, where a total of 30 panelists were recruited on voluntary basis from amongst students at The University of Zambia. The responses for the consumer acceptance test on the three blind coded porridge samples (including one breakfast meal and two composite blend samples) are shown in Table 3. It was observed that there were no significant differences (P> 0.05) amongst the three porridge samples with respect to the attributes of aroma, taste and overall acceptability. There were however, significant differences amongst the three samples with respect to the attributes of appearance and texture. The results further show that the appearance rating of the breakfast meal porridge was significantly higher (7.00%) than that that of the porridge prepared from the 80% blend (6.20) and the 75% blend (5.53).

Table 3: Ratings on attributes of Breakfast meal porridge, MB80 composite blend and MB75 composite blend

Sample type	Appearance	Aroma	Taste	Texture	Overall acceptability
Breakfast meal porridge	7.00±1.72	6.13±1.83	6.20±1.81	7.13±1.70	6.90±1.40
MB80 composite blend	6.20±1.69	5.80±1.73	5.67±1.75	6.13±1.90	6.17±1.51
MB75 composite blend	5.53±1.86	5.57±1.83	6.00±1.82	5.53±1.70	6.10±1.42
Sig	0.008	0.475	0.51	0.003	0.074

Values expressed are means ± standard deviation. Means with different letters in a column are significantly different at (P<0.05).

4.0 Discussion

The protein content of the Mopane worm powder (55.50%) in the current investigation is consistent with what has been reported previously. Other studies reported values of 56.95% and 55.3% respectively [2, 18]. The protein contents of the two blends; MB_{75} (19.04%) and MB_{80} (16.74%), were much higher than the 7% protein prescribed for the breakfast meal according to the Zambia Food Composition Tables [19]. The contribution of Mopane worm powder to the crude protein content of breakfast meal is therefore made significant by the addition of 20% and 25% of Mopane worm powder. Although there are potential nutritional benefits, a higher protein content may result in adverse effects on shelf stability of the composite blends. This is because proteins may undergo reactions that lead to loss of nutritive value in the form of oxidation and the maillard reaction [6]. Due to the effects fat and protein content on the physico-chemical and microbiological stability of particulate foods [6], it is likely that the shelf stability of the composite blends could be lower than breakfast meal especially under conditions of high temperature and relative humidity in storage. However, both blends had a lower moisture content than breakfast meal, which could potentially limit quality degradation reactions that rely on higher moisture levels.

The Mopane worm powder was found to have a higher fat content (10.86%) than both the MB_{75} and MB_{80}. The fat content for Mopane powder in the current study is consistent with what has been reported previously (10.4±0.53 -11.6±0.41%) [20]. It is however intriguing to note that the fat contents of MB_{75} (4.71%) and MB_{80} (5.48%) in the current investigation are way above

the 0.5% fat content prescribed for breakfast meal in the Food Composition Tables for Zambia [19]. This suggests the significant contribution of the Mopane worm powder to the fat content of the breakfast meal. It may also be expected that the shelf stability of the composite blends will be adversely affected due to the higher fat content compared to breakfast meal. Lipid oxidation is known to be a major cause of degradation in food products due to the resulting off-flavors that develop during storage [6]. Despite concerns of the effect of the increased fat content on shelf stability of the composite blends, the higher content of fat in the composite blends implies a potentially higher caloric value compared to breakfast meal of the same amount, which may be helpful in cases where weight gain is the desired outcome.

The ash content of Mopane worm powder was significantly higher than that of the two composite blends (MB_{75} and MB_{80}), which is expected as Mopane worms are considered a nutrient rich food with a variety of minerals including calcium, iron, zinc [20]. Reviews of the Food Composition Tables for Zambia yielded no reported value for total ash content of breakfast meal. However, the ash content of maize and maize products has been reported at a range of 1.10-2.95% [21]. Ash content for both blends falls within this range and as such, it may be established that the contribution of the Mopane worm powder to the ash content of both the MB_{75} and MB_{80}blends may be insignificant.

Literature values for carbohydrate content (8.2 and 7.8%) [18, 2] of Mopane worms that have been reported are lower than the mean value determined in this study. However, the value reported here is consistent with findings in Zambia (11.2-24.6%) [20]. Carbohydrate content of breakfast meal as prescribed in the Food Composition Tables for Zambia is 80g/100g [19]. It is expected that the carbohydrate content of the two both the MB_{75} and MB_{80} blends would be lower than that of breakfast meal due to the substitution of 20% and 25% of Mopane worm powder in 100g of breakfast meal. What is interesting to note is that though the carbohydrate content of the MB_{80} blend was found to be slightly higher than that of the MB_{75} blend, the difference was not statistically significant. The gross energy of the samples was also determined by calculation. There were significant differences between the gross energy of the Mopane worm powder and the two composite blends. The Mopane worm powder had the highest gross energy (375.34Kcal/100g) followed by MB_{80} blend (371.07Kcal/100g) and MB_{75} blend (365.02Kcal/100g) trending least. The findings in this study on the gross energy of Mopane worms are consistent with what has been reported previously (375 - 391Kcal/100g) [20].

A study [20] reported the calcium content of traditionally smoked and dried Mopane worms to be 331.1 - 395.5mg/100g while another [2] documented a 127.8mg/100g content. The calcium contents of all three samples (Breakfast meal, MB75 blend and MB80 blend) were thus much higher than what is recorded in literature. This variation could be attributed to the variability of the diet of wild harvested Mopane worms used in the current investigation in relation to those used in the previous studies. The calcium content of breakfast meal according to the Food Composition Tables for Zambia [19] is 9mg/100g. Despite the variation amongst values reported in literature for the calcium content of Mopane worms, the contribution of Mopane worms to the calcium content of breakfast meal is considerably very high based on the findings of the current investigation. There is therefore a very big potential for the Mopane worm-breakfast meal composite blend (MB_{75} and MB_{80}) to be utilized to improve the contribution of breakfast meal porridge towards calcium intake. The recommended daily intake of calcium for a healthy general population is 945mg/100g based on a 2100Kcal diet [23].

The iron and zinc contents of the Mopane worm powder were found to be significantly different from those of the MB_{75} and MB_{80} blends. Literature [18] reported a much higher iron content for Mopane worms (31.0mg/100g) than what has been reported in this study. This value is higher than those reported [20, 2] (9.98-24.6mg/100g and 26.7mg/100g respectively). The

contribution of Mopane worm powder to the iron content of the breakfast meal blends can be said to be insignificant compared to the iron content of breakfast meal of 2.0mg/100g. This could be the result of particle segregation within the composite blend samples leading to under-reported iron content values [6]. Despite these inconsistencies, it can be said that Mopane worms have the potential to contribute significantly to the daily recommended intake of iron (21mg/100g) according to the Zambia Food Based Dietary Guidelines [22]. Iron is an important mineral present in the red blood cells as part of hemoglobin. It also plays important functions in various enzyme systems, and its deficiency is considered one of the most widespread nutritional disorders in the world [7]. In Zambia iron deficiency in children stands at 21% [24] as such, Encouraging the use of Mopane worms as a fortificant for maize meal could possibly help address this issue.

Similar studies on Mopane worms reported much higher values of zinc than revealed in this study [20, 18]. Review of the Food Composition Tables for Zambia revealed no reported value for the zinc content of breakfast meal. However other literature reports the zinc content of the maize grain to be less than 5mg/100g [25]. It is likely that particle separation and inconsistencies in diets of the Mopane worms contributed to the discrepancies in zinc contents in the current study compared to the previously reported data. However, data on the findings in this study suggest that the contribution of Mopane worms to the Zinc content of breakfast meal could be considerable.

On consumer acceptability, the findings in this study reveal that appearance of the breakfast meal porridge was more preferred than the two blends. However, between the two blends, the MB_{80} blend was significantly more preferred than the MB_{75} as it was noticeably lighter in color. Literature points out that regardless of a products utility or nutritional value, overall consumer acceptability and ultimately demand for the product can be affected by its appearance [26]. In support of this, it has been found that about 70% of households in Lusaka preferred breakfast meal to roller meal in spite of it being costlier [27]. The preference for breakfast meal was attributed to its appearance and taste. The finding that the texture for breakfast meal porridge was more preferred than the blend can be explained by the formulation procedure which included sieving of the mopane worm powder and repeated intermittent blending of the dry ingredients. The particle size differences between the breakfast meal and the Mopane worm powder were likely to have contributed to the texture of the porridge being more negatively perceived. It was observed that moisture build-up and gelatinization of the porridge samples occurred rapidly in the plastic containers used to serve the porridge to the participants prior to their evaluation of the samples. This was expected and as such effort was made to ensure that the time between preparation and serving was as short as possible. However, it is worth noting that these occurrences may have contributed to the negative perception of the attributes of appearance and texture of all three sample types.

Conclusion

The study revealed that Mopane worm powder (MP) made from the Mumpa kaseke variety has considerable amounts of macronutrients (protein, crude fat and crude fiber) and minerals (calcium, iron and zinc) that could possibly be valuable in local dishes and Food Based Fortification. Both composite blends (containing 20% and 25% Mopane worm powder) were found to be more nutritionally rich in macronutrients (protein, fiber and fat) and calcium compared to breakfast meal. While more research and investigations are required regarding the nutritional composition of Mopane worms and other edible insects to support existing data, there is a significant information to argue for the high nutritional value of Mopane worms.

Other edible insects may also be identified for use as food based fortificants and compared with each other.

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APPENDIX A: FIGURES

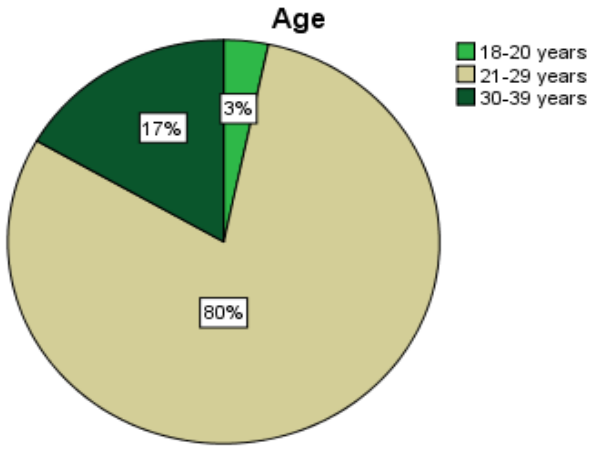

Figure 1: Age categories of sensory evaluators

Data shows that 80% of the panelists were aged 21 and 29, 83% of them were male while 63% of them only consumed insects on special occasions.

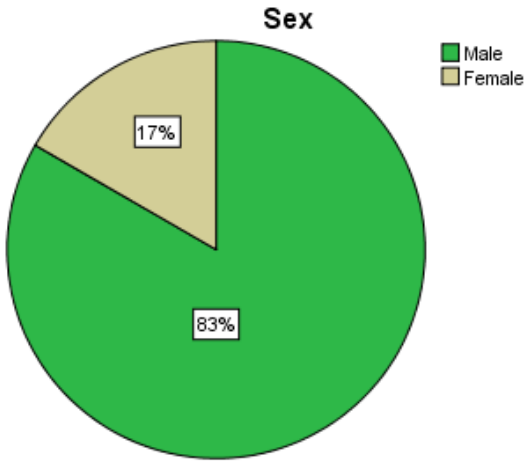

Figure 2: Proportion of respondents who participated in sensory evaluation

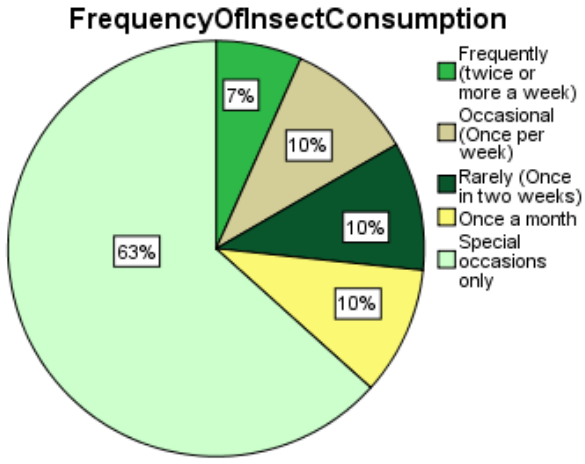

Figure 3: Frequency of eating edible insects among the study respondents