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Mopane Worm (*Gonimbrasia belina*) Utilisation, a Potential Source of Protein in Fortified Blended Foods in Zimbabwe: A Review

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Keywords: mopane worm, insects, nutrition, fortified blended foods, proteins.

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MOPANEWORMGONIMBRASIABELINAUTILISATIONAPOTENTIALSOURCEOFPROTEININFORTIFIEDBLENDEDFOODSINZIMBABWEAREVIEW

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Mopane Worm (*Gonimbrasia belina*) Utilisation, a Potential Source of Protein in Fortified Blended Foods in Zimbabwe: A Review

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Abstract- Primarily, Mopane worm (*G. belina*) forms a major part of the most consumed and highly nutritious (protein averages 55.41%) insect in Zimbabwe. The insect offers a great potential source of protein that could be utilised to alleviate diet deficiencies diseases among most vulnerable groups in society. The insect could form a foundation for new food products that are based on its substantial nutritive value. The paper reviews nutritional potential of G. belina to the human diet through its use in fortified blended foods (FBFs) formulations, making it an alternative substitute for conventional sources of protein, such as soybean, common bean and nuts. In view of that, *G. belina* through FBFs could be used as food aid in humanitarian relief programs in Zimbabwe in fighting against rampant malnutrition especially among rural population and urban dwellers. However, several aspects related to food safety and sustainability in insects harvesting are of great concern that needs to be underscored. Further research would be necessary to ascertain the real process development and formulation of FBFs where *G. belina* has been exploited as a source of protein.

Keywords: mopane worm, insects, nutrition, fortified blended foods, proteins.

I. Introduction

Entomophagy is regarded as a practice of eating insects as food (Srivasatva and Naresh Badu, 2009; Gahukar, 2011). FAO/WHO (2013) estimated that, nearly 1,900 insect species has shown to be edible worldwide, mainly in developing countries such as Zimbabwe (Glew *et al.*, 1999; Ghazoul, 2006; Dube and Dube, 2010). Guhukar (2011) considered, edible insects as natural renewable resource of food that provides nutritional, economic and ecological benefits to the communities. According to Dube and Dube (2010), *G. belina* is the most consumed insect in most communities of Zimbabwe in both rural and urban settlements constituting parts of the traditional diets.

As a global obligation, the Food and Agriculture Organization (FAO, 2010a; FAO., 2010c) of the United Nations initiated a policy and recommended programs that will use insects as a source of protein to feed people. Several authors confirmed that, insects are nutritious food that provide proteins (amino acids including methionine, cysteine, lysine, and threonine), carbohydrates, fats, some minerals and vitamins, and have high energy value (Capinera, 2004; Johnson, 2010; Xiaoming *et al.*, 2010). For instance caterpillars to which *G. belina* belongs, contain proteins to the extent of 50–60 g/100g dry weight. In addition insects proteins are highly digestible (between 77% and 98%) (Ramos-Elorduy, 1997a), although presence of chitin lowers their digestibility, but its removal greatly increases the quality of insect protein (DeFoliart, 1997). Equally, humans digestive flora is able to digest chitin due to the presence of two catalytically active chitinases namely AM Case and chitotriosidase (Van, 2003; Synstad *et al.*, 2004; Paoletti, 2005; Muzzarelli *et al.*, 2012) which alternatively works in different pH ranges (Boot *et al.*, 1995; Renkema *et al.*, 1995; Boot *et al.*, 2001; Chou *et al.*, 2006).

Apart from the above reason, nutritious foods derived from insects present a new available source of protein and requisite step to alleviate food security problems in many developing countries (Kent, 2002; Rowe *et al.*, 2008; Gahukar, 2009; Kumar, 2010). According to Gahukar (2009), food security in developing nations has become problematic due to increased population growth, consumption and demand patterns (Beddington, 2010) and possible decline in food availability. This is against a backdrop in agricultural productivity exacerbated by recent rampant natural factors such as climate change, energy crisis, decreasing soil fertility, incidence of pests and plant diseases, and man-made situations such as lack of purchasing power of consumers and disparity in food distribution (Kumar, 2005; Kumar, 2010; Gahukar, 2011). Currently, adequate human nutrients in form of FBFs are complemented by plant seeds such as soybean (as corn/wheat soya blend), cowpeas, nuts and common bean which are productively on a downward trend (Moreki *et al.*, 2012). Consequently, chronic malnutrition is rampant in many developing nations (Gahukar, 2011; Kinyuru *et al.*, 2011; FAO/WUR., 2013) especially to vulnerable group of the society such as children and lactating mothers (Oniang

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and Mutuku, 2001; ENCU, 2004). Hoppe et al. (2008) stated that, malnutrition promotes various childhood diseases leading to their death. Furthermore, it accelerates rate of unemployment, illiteracy and impedes overall socio-economic development in many developing nations.

In view of the above, Kinyuru *et al*. (2010) and FAO/WUR, (2013), supported use of insect as a food ingredient that enhances both food`s nutritional quantity and quality. Bukkens (2005) confirmed that, insects are commonly mixed with, or often consumed as supplement to predominant diets centred on maize, cassava, sorghum, millet, beans and rice, and form an ingredient to produce other food items. In line with that, Ekpo and Onigbinde (2005) produced bread containing grubs of the African palm weevil (*Rhynchophorus phoenicis)* that provides major and minor nutrients essential for body growth (Ekpo and Onigbinde, 2005). In addition to that, in Kenya wheat buns were enriched (5% mix) with the termite (*Macrotermes subhyalinus)* (Gahukar, 2011), whereas in Mexico, a thin flat bread made from finely ground maize was enriched with ground mealworm *Tenebrio molitor* larvae (Aguilar-Miranda *et al*., 2002) and in Nigeria termite *Microtermes bellicosus* Smeathman are used to enrich maize protein (Bukkens, 1997).

Likewise, global food security problem particularly in developing countries including Zimbabwe (Moreki *et al*., 2012) is a serious challenge that needs to be addressed in the near future. Increased population growth as opposed to rapid decrease in crop and animal productivity, food and nutritional adequacy pose grave challenge to adequate food security. In view of this development, the production of adequate human nutrients such as protein from crop and animal husbandry represents a serious challenge for the future (van Huis, 2012; FAO/WUR., 2013). Therefore, this paper seeks to review *G. belina* utilisation, as a potential source of protein in FBFs in Zimbabwe. The main purpose of this review is to evaluate whether the nutritional potential of *G. belina* could be harnessed into human diet through FBFs as a potential alternative substitute for conventional protein sources such as soybean. Consequently, this review also briefly summarizes the nutritional composition of both *G. belina* as comparable to other conventional protein sources such soybean, cowpea, common bean just to mention a few. If FBFs containing *G. belina* is commercialised and introduced as a FBF to selected vulnerable groups, it may seal a gap between plant and animal based FBFs, wherein the later contain much needed essential animal protein and fats. The review also emphases on probable food safety and sustainability challenges encountered when utilizing *G. belina* in FBFs. In line with this review further work needs to be undertaken to ascertain actual process development and formulation of FBFs where *G. belina* has been utilised as a source of protein.

a) *Fortified Blended Foods used in Zimbabwe*

According to the World Food Programme (WFP), FBFs are regarded as Specialised Nutritional Foods (SNF) used to improve the nutritional intake of people in need of assistance world-over. Likewise, Hoppe *et al*. (2008) confirmed that FBFs consist of a mixture of cereals, pulses, fats, vitamins, and minerals intended to provide a balanced intake of essential nutrients for vulnerable groups. However, Rowe *at al*. (2008) stressed the need of FBFs to contain adequate calories (400kcal/100g) and protein (15g/100g), fortified with essential micronutrients. SNFs might also include micronutrient powders, Ready-to-Use Foods and High-Energy Biscuits (HEBs). According to Hoppe *et al*. (2008), FBFs are used on a very large scale to feed populations in most developing countries, especially malnourished individuals and vulnerable groups (Hertz, 1997; Rowe *et al*., 2008). Rowe *et al*. (2008) estimated that, around 50%, 20% and 15% of FBFs are distributed globally in Africa, Asia and Latin America and the Caribbean continent respectively. In Zimbabwe alone USAID (2012) reported that, for the period between 2007 and 2011 WFP distributed 43223mt of corn soy blend (CSB) and 602844mt of cereal (maize, sorghum, wheat, rice included) (USAID., 2012).

Hoppe *et al*. (2008) reiterated that, CSB and wheat soy blend (WSB) are the most commonly used FBFs. In Zimbabwe CSB and WSB are the most predominantly distributed FBFs. They are made from the most common or staple grains mainly cornmeal or wheat meal. According to Anonymous (2011), the cereal component provide the largest proportion of energy, a large part of the protein and significant amounts of micronutrients for those dependent on food aid. In addition to that, the soy flour component acts as an important source of protein and provide a range of micronutrients. The blend is mixed and fortified with mineral-vitamins premix sourced from a reputable supplier such as Roche (Anonymous, 2011). Other types of FBFs exist based on sorghum and soy, bulgur, wheat and soy, or combinations of cereals with heat-treated soy in its full fat form or as defatted flour. There are also FBFs that contain milk, corn soy milk (CSM) and wheat soy milk (WSM) (Hoppe *et al*., 2008). WFP has given specifications for the energy, protein, and fat content of the FBFs (Table 1) According to Hoppe *et al*. (2008) CSB consists of; 80% maize and 20% soy, and WSB consists of; 75% wheat and 25% soy. However, FBFs containing *G. belina* is not available and have not been formulated mainly because of lack of adequate studies that have been done to evaluate its suitability based on its extensive nutritional information.

Table 1 : Nutritional value of commonly used food aid commodities (FBFs)

Food commodity (100-200g)	Key ingredients	Energy (kcal)	Protein (g)	Fat (g)
Super cereal plus	Corn/wheat/rice soya, milk powder, sugar, oil, Vitamins &Minerals	394-787 kcal	16-33g (17%)	20g (23%) contains EFA
Super Cereal	Corn/wheat/rice soya, Vitamins & Minerals	376-752 kcal	15-31g (16%)	8-16g (19%)

Source: (WFP., 2013) Specialized Nutritious Foods Sheet

b) Conventional Protein Sources used in Fbfs in Zimbabwe

In Zimbabwe emergency cases which include severe droughts, floods just to mention a few are on an increase thereby placing demands on government and donor community to provide food aid on affected communities. The Government and the donor community are normally involved in providing food (FBFs included) to the affected people. The most common emergency food packages are in the form of maize, which is the staple crop, bulgar, rice, iodised salt, vegetable cooking oil, wheat flour – all which are energy foods; specially formulated food mixes like CSB, WSB, dried kapenta fish, dried legumes (sugar beans, soy, cowpeas, lentils chickpeas, peas, etc) all forming a protein rich component in the food aid.

i. *Soybean (Glycine max)*

Several authors confirmed that, families from Nigeria, Zimbabwe and Kenya that grow and utilise soya been in their diets are healthier than those families that do not use soybean as part of their diets (Mendel and Fine, 1912; Adelodun, 2011). This is owed to great invaluable nutritive and health benefits furnished by soy based products, hence a huge need for a renewed, concerted effort and sustainable incorporation of soybean into African diet. The International Institute of Tropical Agriculture (IITA) soybean success story recorded in Nigeria, Zimbabwe, Uganda and South Africa must be replicated in other African counties (Adelodun, 2011). Mature raw soybeans has a proximate; protein composition of 40.1 - 44.5%, (Table 2) (Da Silva, 2009), though it adequately provide sufficient amount of carbohydrate, digestible fibres and minerals etc. In addition to its high food value, it is one of the least expensive sources of protein when compared to eggs, milk, beef, and cowpea (IART&T., 1998; Adelodun, 2011). Soybean seeds are the most common protein source of fortified blended foods in Zimbabwe. According to the (WHO/FAO, 2007) soybean seeds processing into floor should secure optimum flavour and palatability, as well as to control such factors as trypsin inhibitor, hemaglutinins and other anti-nutritional factors.

ii. *Common bean (Phaseolus vulgaris)*

According to (Gajzaho, 1998) Phaseolus vulgaris is also known as French, garden, haricot, kidney, pinto, navy black, pink, black eye, cranberry, great northern or dry bean and is consumed by humans as green in pods (canning and freezing) or dry seeds. In Zimbabwe common bean is grown for domestic use in rural areas countrywide, consumed as relish and surplus is disposed of to commercial markets. In times of drought, donor agencies supply protein rich common bean as a food supplement. In general, *Phaseolus vulgaris* contains about 15.1-15.4% protein, 48.5-49.5% carbohydrates, and 15.7-15.9% fat and small amounts of other nutrients (Table 2) (Audu & Aremu, 2011).

iii. *Cowpea (Vigna unguiculata)*

Vigna unguiculata is known to be a low input legume crop grown throughout Zimbabwe and Africa. The chemical composition of cowpea is similar to that of most edible legumes. In general, the cowpea contains about 15.5-15.7% protein, 60.2-60.9% soluble carbohydrates and small amounts of other nutrients (Table 2) (Alayande et al., 2012). The cowpea is mainly grown in the rural areas for domestic use and if higher yields are obtained the surplus crop is preserved and used in times of poor harvest. Several authors confirmed that, cowpea seeds resemble other legumes in their potential contribution to protein nutrition based on amino acid profile (Omueti and Singh, 1987; Nielsen et al., 1993; Alayande et al., 2012). In addition cowpeas are lower in anti-nutritional factors than many other legumes as reflected by moderately high protein efficiency ratio values even in unheated seed (Phillips, 1982). Likewise, research has been applied to develop new food ingredients and products made from cowpea and other starchy legumes (Zamora and Fields, 1979; Sosulski *et al.,* 1982). Although cowpea is mainly consumed in cooked form, (Aykroyd *et al.,* 1982) stated that not all anti-nutritional substances are completely destroyed by this thermal treatment. Cowpeas are known to have a content of anti-nutritional factors and some of these are acquired through fertilizers and pesticides together with naturally-occurring chemicals (Igile, 1996). Moreover, the consumption of cowpea seeds can come with an added risk of exposure to mycotoxins and their health risks.

iv. *Groundnut (Arachis hypogaea L.)*

Hildebrand (1982) stated that, in Zimbabwe more than 90% of the groundnuts production comes from the rural areas, and this sector retains about 90% of its production for local use. Most of the agricultural industry is in the central plateau region on elevations between 300 and 1600m, although cropping below 800m is largely dependent on irrigation. The highest reported field scale yield in the world was in Zimbabwe, 9.6tonnes /ha of unshelled nuts (Hildebrand, 1982). Groundnut (peanut) is among the major oilseeds in the world. The peanut cultivar plays an important role in the economy of several countries (China, India, U.S.A. Netherlands, Germany, Russia, and Spain) (Campos-Mondragon et al., 2008). Raw groundnut seeds contain 23.5-26.6% protein, 49.8-53.4% fat and 18.9-23.4% carbohydrates (Table 2) (Ayoola, *et al,* 2012). Traditional processing methods like for example roasting and de-hulling combined increased, crude protein, ash, content while fat, carbohydrate fibre and decrease anti-nutritional factors such as phytates, condensed tannins, trypsin and alpha-amylase inhibitors (Ejigui *et al.,* 2005). In Zimbabwe ground nut seeds are consumed at various stages of maturity levels in their raw state, boiled or heat treated. The ground nut is also roasted and crushed to form a paste used as bread spread and as a chief ingredient of a number of traditional relish stews. The high oil and protein content of the seeds make it suitable for use as a common ingredient in the cooking of porridge for all ages.

Table 2 : Conventional protein sources nutritional composition (g/100g)

Source	Proximate analysis contents (g/100g)				References
	minerals	proteins	carbohydrates	fats	
Glycine max	-	40.1 - 44.5	30.6 - 34.4	18.2 – 20	Da Silva, 2009
Phaseolus vulgaris	3.9-4.9	15.1-15.4	48.5-49.5	15.7-15.9	Audu & Aremu, 2011
Vigna unguiculata	3.8-4.4	15.5-15.7	60.2-60.9	2.2-2.6	Alayande et al., 2012)
Arachis hypogaea L.	2.0- 2.5	23.5-26.6	18.9-23.4	49.8-53.4	Ayoola, et al, 2012

c) *Mopane Worms (G. belina) distribution in Zimbabwe*

Several authors confirmed that, *G. belina* is the most popular and lucrative caterpillar on the African continent (Timberlake, 1995; Timberlake, 1996; Dube and Dube, 2010; FAO/WUR., 2013). Dube and Dube (2010) and Moreki *et al.* (2012) agreed that Mopani worm feed almost absolutely on the leaves of the Mopane tree, *Colophospermum mopane.* The mopane woodlands in Zimbabwe are mainly found in the southern districts for instance in Chivi, Mberengwa, Mwenezi, Beitbridge and Chiredzi etc. According to Timberlake (1995), Mopane tree is foremost over large tracks of moderately clay soils (without extreme water logging) in southern Africa (Zimbabwe included) within an altitudinal range of 300-1000m (even up to 1200m in Zimbabwe, (Figure 1)) and annual rainfall zone of 400-700mm with a long dry season. The geographical distribution of Mopani worm lies within the Mopane woodland belt or districts as shown in Figure 1 and other host plants (Gardiner, 2005). Viljoen (1989) reported that, the same tree could be found in area with as little rainfall as 100mm. Similarly, in Zimbabwe as shown in indicated districts in Figure 1, the Mopani worm is located in the semi-arid regions (natural region IV and V, where there are little or no commercial agricultural activities and communities rely mostly on drought resistant crops such as sorghum and millet (Viljoen, 1989). Unreliable climate causes regular failure of staple grains and a high level of vulnerability to food insecurity especially in those districts indicated in Figure 1. Traditionally, Mopani worms have been harvested for subsistence use by rural households (Ashipala *et al.,* 1996) and they are thought to make a significant contribution to rural diets, although there has never been a proper assessment.

The Mopani worm is bivoltine in most areas that is, two generations are produced each year. The first major outbreak being between November and January followed by a minor second outbreak between March and May (van Voorthuizen, 1996; Stack *et al.,* 2003; Gardiner,2005). However, van Voorthuizen (1976) pointed out that Mopani worm population numbers vary from year to year at a single locality though (Roberts, 1998) was quick to point out that the population numbers are on the decrease as a result of increase in their exploitation, declining selective harvesting (Hobane, 1995) and general decrease on the Mopani woodlands due to deforestation.

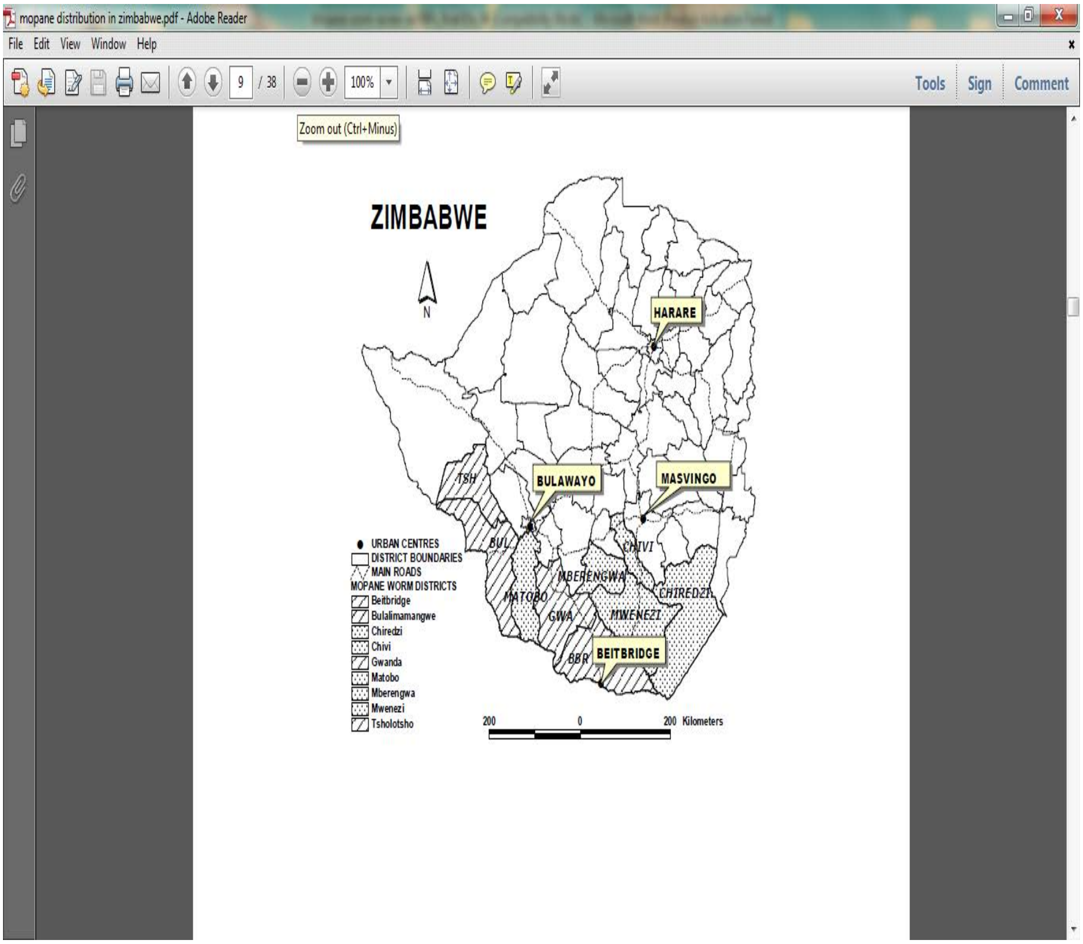

Figure 1 : G. *belina* distribution in Zimbabwe by district

d) Mopani Worm (G. belina) harvesting and processing

Essentially, *G. belina* requires ecological harvesting so as to ensure a good crop for the following season. According to Dube and Dube (2010), a woodlot of 4000 hectares would support 19 million worms, which would translate to193 tonnes of Mopane worms. Normally, *G. belina* life cycle start in October when the eggs hatch marking the first generation. Wiggins (1997), Timberlake (1996) and Toms (2001) confirmed that, young Mopane worms or larvae feed on the leaves of the Mopane trees where they hatch and as they grow, molt 4 times (there are five larval stages) before they reach their maximum size. FAO (2010a) indicated that, principally Mopane worms are gathered by hand from the ground and from the trunks, branches and leaves of the trees. In some cases trees or branches are cut and the larvae harvested. The Mopane worm has a tough skin and is protected by black or dark reddish brown spines which can be painful and cause lacerations and the spines and associated hairs seem to have a slight rusticating effect. In addition, when the larvae are handled, they often exude a slimy green fluid from the mouth (Gardiner, 2005). According to Kozanayi & Frost (2002) the fluid irritates any scratches on the hand, so hand protection (by use of gloves) helps their harvesting and degutting. Taylor (2003) noted that, traditional method of degutting by hand is common and faster, hence the most preferred method (Kozanayi and Frost, 2002).

Soon after harvesting, Mopane worm can be kept in live storage for a maximum of 3 days (FAO, 2010a). After being degutted, washed and usually cooked using water and salt (Taylor, 2003) (for 30 minutes and sun dried for 2 hours (Allotey and Mpuchane, 2003), the larvae can be preserved by either sun-drying or smoking. Drying degutted Mopane worms prolongs their shelf life to almost a year therefore maintaining a steady supply of protein in the diet of the people in the area. Thereafter, the Mopane worm will be ready for storage in polythene bags. FAO/WUR, (2013) pointed out that considerable amount of care should be taken to avoid contamination throughout the various processing stages to ensure safe product.

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e) Proximate composition of Mopane Worms (G. belina)

G. belina is the most common specie of the Mopane worm. According to Moreki *et al.* (2008) although the Mopane worm is seasonal, it provides a readily available and cheaper source of animal protein. The Mopane worm contain comparatively higher quantities of protein, fat, carbohydrate valuable minerals than beef and chicken (Moreki *et al.*, 2012) However, the Mopane worm contain 27% chitin of dry weight (Sekhwela, 1989; Ohiokpehai *et al.*, 1996; Majeti and Kumar, 2000) which blocks digestive enzyme accessing protein and lipid substrates thereby reducing the utilisation of the these nutrients (Mahata *et al.*, 2008). Above all, increase in roughage intake for instance chitin through Mopane worm) reduce some gastro-intestinal diseases, hence this makes the insect an all-rounder in providing nutritious balanced meal (Illgner and Nel, 2000; Mpuchane *et al.*, 2000; Mohapatra *et al.*, 2002).

Besides being used as a protein source by people in semi-arid environments of Botswana, Namibia, South Africa and Zimbabwe (Marais, 1996; Styles, 1996), Mopane worms could also be used in animal feed formulations (Mpuchane *et al.*, 2000). Several authors confirmed huge growing interest in Mopane worm as a food resource for both human and animals in the near future (due to its excellent nutritional information, Table 3) (Illgner and Nel, 2000; Mpuchane *et al.*, 2000; Ghazoul, 2006). According to Siame *et al.* (1989) and Madibela *et al.* (2007), *G. belina* contains about 50% crude protein and is abundant in the wilderness during its season of availability. Madibela *et al.* (2009) reported that, degutting improves the crude protein concentration of the worms by 10%. Although *G. belina* has been used as part in day to day meals in Southern Africa because of its nutritional value, but to date it has not been used as a protein source in fortified blended foods. Based on it nutrients composition it can be a good alternative source of protein instead of some convectional sources of proteins such as soybean.

Table 3 : Mopane worm *(G. belina)* nutritional composition

Contents	*Mean value
Crude protein (%)	55.41
Digestible protein (%)	53.3
Carbohydrate (%)	8.16
Ash %	8.26
Neutral detergent Fibre %	27.8
Acid Detergent fibre %	16
Acid detergent Lignin	5.2
Acid Detergent Insoluble Nitrogen (%)	0.9
Fat (%)	16.37

Potassium (mg/g)	35.2
Calcium (mg/g)	16.0
Phosphorus (mg/g)	14.7
Magnesium (mg/g)	4.1
Iron (mg/g)	12.7
Zinc (mg/g)	1.9
Sodium (mg/g)	33.3

**Mean value calculated from various sources*

Source: (Dreyer and Wehmeyer, 1982; Illgner and Nel, 2000; Gardiner, 2003; Gardiner, 2005; Madibela et al., 2009; Moreki et al., 2012; Simone et al., 2013)

f) Mopone worm sustainability and rural community livelihoods enhancement

Importantly, harvesting caterpillars for human consumption has positive and negative impacts on forests. FAO (2010a) noted that, reducing caterpillar populations is beneficial to host trees, although harvesting practices that include cutting of branches or felling trees contribute to forest degradation and deforestation. In line with that, Roberts (1998) indicated that a decline in the abundance of Mopane worms was mainly due to increasing exploitation of Mopane trees (Hobane 1995), a general increase in pressure on Mopane woodlands, and increased frequency of drought. In support of that, Bartlett (1996) indicated evidence from parts of Botswana where Mopane moths had disappeared after heavy harvesting. In addition to that, frequent veld fires may reduce populations of edible caterpillars at the expense of non-edible beetles which pose a threat to food security and nutrition (Flower *et al.*, 1999; FAO, 2010a).

Flower *et al.* (1999) emphasised that, the economic importance of Mopane woodlands can only be meaningful if more ecological studies are done on the tree species thereby unlocking potential in Mopane worm farming. Above all, little nutritional information is known about the *C. mopane* leaves at different times of the year in which Mopane worm is harvested. Likewise, Ditlhogo *et al.* (1997) highlighted little information on growth rates of Mopane tree (on *which G. belina* depend) under various conditions, as major limitation in the ability to manage and utilise Mopane worms. In addition to that, Mopane worm geographical variability in outbreak occurrence may also lead to conflicts between community members (Ghazoul, 2006).

Gardiner *et al*, (2005) reported that, *G. belina*, and mopane woodland products are key resources to poor farmers and landless poor people across southern Africa. In line with that, De Foliart (1995) and Styles (1995) revealed substantial value in Mopane worm trade. For instance in South Africa alone, the commercial value of Mopane worm harvests can reach $3,000 per ha, amounting to annual sales of $1.6m. Also in Botswana, the Mopane worm harvest in a good year is estimated to be worth $3.3m, providing employment and income to 10,000 people. However, the irregular and largely unpredictable nature of Mopane worm outbreaks results in price fluctuations and uncertainty of supply, both undesirable outcomes for poor and risk inflicted farmers (Gardiner, 2005; Ghazoul, 2006).

II. Product Quality and Food Safety

Essentially, Mopane worm processing, packaging and storage practices are chiefly regarded as poor and most leading causes of their spoilage by micro-organisms or fungi. In this regard, thin plastic bags are often used and are easily punctured by remaining spines on the dried product leading to infestation by pests and uptake of water (Gardiner, 2005). Klunder *et al.* (2012) pointed out that, insects like many meat products, are rich in nutrients and moisture, providing a favourable environment for microbial survival and growth. Accordingly, adequate hygienic handling and correct storage of Mopane worm should be strongly addressed, in order to avoid and reduce potential hazards during consumption (Klunder *et al.*, 2012; Belluco *et al.*, 2013). According to Nyakudya, (2004), Mopane worm are traditionally kept in polypropylene woven bags in which maize or a similar product has been stored, plastic or metal buckets and clay pots. All these items are prone to contamination and spoilage (Allotey *et al.*, 1996; Nyakudya, 2004). Taylor (2003) indicated that later on during storage Mopane worm get infested and appropriately fumigated using Phostoxin gas. Nevertheless, Phostoxin gas is dangerous and only registered pest control operators are permitted to use it. In contrast, effort has been made to improve on Mopane worm shelf life as well as its hygienic processing mainly through solar radiation method (Dube and Dube, 2010).

Even though there is enough literature to support the high level of protein in *G. belina,* the insect has some challenges. According to Sekhwela, (1989) and Ohiokpehai *et al.*, (1996), *G. belina* contains chitin, a component of the outermost part of the worm, which forms 27% of the dry weight. Chitin physically blocks the access of digestive enzyme to hydrolyse protein, lipid, fat-soluble vitamins and minerals thus affecting their utilisation (Mahata *et al.*, 2008; FAO., 2010a.). In contrast, (Koide, 1998) stated that chitin and chitosan can bind dietary lipids, thereby causing reduction in cholesterol and triglycerides in blood plasma due to reduced absorption of lipids in intestines. Majeti and Kumar (2000) also confirmed that chitosan is a fat trapper in the stomach, hence prevents absorption of trapped fat. However, experiments on silkworm pupa by (Zhang *et al*., 2000; Paulino *et al*., 2006) demonstrated the significant value of chitin as a source of fibre and calcium hence enabling production of protein concentrates from de-chitinised insects. Gardiner (2005) indicated that, Mopane leaves (on which *G. belina* feed on) are generally not favoured by vertebrate browsers and are used only in drought years implying that they likely contain plant defence compounds such as phenolic and tannins signifying presence of antinational factors.

The global growing consumer demands for safer and healthier foods have raised concerns over insects handling and processing practices, hygiene and overall food safety. However, FAO (2010b) regarded insects as "health foods" only when collected from forest areas when they are generally clean and free of chemicals. Belluco (2013) emphasised occurrence of chemical hazards in insects as dependent, mostly on habitat and plant feed contamination and can only be controlled by selected farming and dietary conditions. Among insect-related chemical hazards are cyanogenetic substances which can also be present in insects (*Lepidoptera* in which *G. belina* belongs). Blum (1994) reported that presence of these substances in insects cause inhibition of enzymes such as succinate dehydrogenase and carbonic anhydrase, thereby inhibiting some metabolic pathways for instance oxidative phosphorylation. This is due to the fact that cyanogenetic substances have a high affinity for ferrocytochrome oxidase (Blum, 1994).

Ingestion of caterpillars (to which *G. belina* belongs) is common in children, probably due to their natural interest. Lee and Hathaway (1998) reported children who had accidentally ingested caterpillars suffered from symptoms comprising drooling, difficulty swallowing, pain, and shortness of breath. FAO (2010a) insisted that, ingestion of caterpillars may provoke toxic reactions, even when symptoms suggest an underlying allergic reaction (Okezie *et al*., 2010). However, few studies have been conducted on allergic reactions due to insect ingestion. Therefore, there is a need for further research to ascertain the risk of food allergy after insect consumption, though a thorough thoughtfulness is essential in differentiating toxic and allergic symptoms (Lee and Hathaway, 1998; Pitetti *et al*., 1999). Importantly, ingestion of *G. belina* can cause anaphylactic shock. Okezie *et al*. (2010) reported the case of a 36 year old female who had two different episodes of anaphylactic shock after *G. belina* consumption, though no allergic reaction test was performed.

III. Conclusion

G. belina has high nutritional value and abundant in most parts of Zimbabwe making it a highly potential sustainable food source in human nutrition. The insect is a rich source of good protein including essential amino acids, fats and other nutritive elements, vitamins and carbohydrates for the human body (Capinera, 2004; Johnson, 2010; Xiaoming et al., 2010). Conclusively, *G. belina* average protein value is higher, (all calculations based on various sources) for instance it is approximately 55.41% (based on dry weight) as compared to current conventional sources from Glycine max (40.1 - 44.5%), Phaseolus vulgaris (15.1-15.4%), Archis hypogaea. L. (23.5-26.6%) and Vigna unguiculata (15.5-15.7%) (all calculations based on dry weight). In view of the above, *G. belina* appears to be a potentially equal protein substitute for proteins when used in FBFs formulations. Besides having the highest protein value per hundred gram of dry weight (g/100g), it is also an animal based nutrition source that can also provide all the essential proteins and fats that are not supplied by plants based foods (Capinera, 2004; Johnson, 2010; Xiaoming et al., 2010) (Ramos-Elorduy, 1997a). Above all, *G. belina* is considered as a cheap source of animal protein containing comparatively higher quantities of protein, fat, carbohydrate valuable minerals than beef and chicken (Moreki et al., 2012). On the other hand *G. belina* had found to be a key resource to poor farmers and landless poor people (Gardiner, 2005) who could exploit it to improve their livelihoods (Styles and Skinner, 1996; De Foliart, 1997). However, food hygiene issues and safety are of paramount importance to the viability of this sector if it is to attain global recognition (FAO., 2010a. ; FAO/WUR., 2013). Finally, *G. belina* utilisation as an alternative protein source in FBFs formulation is feasible in Zimbabwe, especially when commercially produced and harvested at large scale through participation of small holder community farmers. However, FBFs containing *G. belina* are not available and have not been formulated mainly because of lack of adequate studies on its feasibility accompanied by absence of process development for the production of FBFs containing the insect.

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