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Original Research Article

Insects for Food: A Review of Potential Characteristics in Honey Bee Brood and Pearl Millet for Malnutrition Prevention and Resolution

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Abstract: Honey bee brood (lava and pupa stages of honey bee) and pearl millet are two food items that are locally available in Kenya, culturally accepted and often consumed in many parts of the world including Arid and Semi-Arid Lands (ASALS). However, there is limited documented literature on characteristics of pearl millet and honey bee brood. Such information is important to inform production, processing, and value addition. This systematic literature review aims to determine the nutritional composition, use, acceptability, strengths and threats, as well as effects (on weight, height or biochemical composition in children) of pearl millet and honey bee brood. A total of seventy relevant articles published in 1980 to 2023 searched on Cochrane Library, PubMed, and Google Scholar were included in the study. Pearl millet was presented to have high calorie, and balanced micronutrients. On the other hand, honey bee brood was described as rich in protein, fats, vitamins, and minerals. Combining the two in conventional diet would provide adequate nutrients for humans when utilized as food. Due to presence of high contents of balanced amino acids, especially leucine, histidine and the high caloric nature of pearl millet and bee brood, the two can be promoted for malnutrition prevention and resolution in the arid and semi-arid lands where they are produced.
Keyword: Pearl Millet, Honey Bee Brood, Acute malnutrition, Supplementary Food.

1.0 INTRODUCTION

Poor dietary intake, is a persistent, common problem worldwide evidenced by millions of persons with malnutrition (Food and Agriculture Organization of the United Nations (FAO) 2010). About 690 million persons globally (8.9%) are undernourished (FAO, 2019), mainly children below five years, where 7.1% of Africans, and 4.2 percent of Kenyan children are included (United Nations Children's Emergency Fund (UNICEF), World Health Organization (WHO), World Bank Group (WBC), 2020). In Kenya, wasting is mainly concentrated in Arid and semi Arid lands (ASALs) and poor urban settings (Kirogo, 2019). Therefore, promotion and use of locally produced nutritious food for malnutrition prevention and resolution is an urgent agenda. Knowing the characteristics and nutritional value of such foods contributes to certainty when advocating for adoption, production, use and processing of such foods.

Pearl millet, (bulrush millet, Pennisetum glaucum), is a cereal grass, mainly cultivated in the semi-arid regions in subsistence small-scale farming (Bhagavatula, 2013; USDA, 2015). From the previous literature, it is demonstrated as the sixth highest produced and consumed cereal crops (after rice, wheat, maize and sorghum) in Sub-Saharan Africa (FAO 2010; FAO, 2016; Uzom, 2010; Yadav, 2011; Rwomushana, 2012; Mgonja, 2012; Kumara, 2016). Previously, it is hypothesized that adoption and consumption of pearl millet may improve food and nutrition security in semi-arid zones of Sub-Saharan Africa (Yadav, 2011; Saleh, 2013; Kumara, 2016). However, pearl millet has remained under-produced, under-processed and underutilized (KARI (Kenya Agricultural Research Institute, 2006; Mweu, 2013), making it stagnate to a subsistence crop especially in East and central Africa regions in which Kenya lies.

On the other hand, Honey bee which is a well domesticated insects has been proposed and consumed

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as food (Crane, 1985; Kazembe, 2022). However, though Bee keeping is well promoted as an economic activity in the ASALs, there is low adoption as represented in low honey production in many parts of the world (Government of Kenya (GoK), 2008). Only 20% of honey market demand is achieved (GoK, 2008). Moreover, honey bee brood, which is one of the byproducts of the bee hive has limited use, processing and production. Additionally, there is limited data on nutrient composition, processing and use as food.

This study therefore aims to review and gather all published literature on pearl millet and Honey bee brood to determine the nutritional composition, acceptability, use, weaknesses strengths as well as effects on weight, height or biochemical composition when consumed.

2.0 STUDY DESIGN AND METHODOLOGY

A review of the existing literature was conducted using electronic databases on PubMed, Cochrane Library, and Google Scholar. Relevant articles published from 1980 up to 2023 were included. Studies reporting on the the nutritional composition, use, acceptability, effects on humans when consumed, strengths and threats for use as food and supplement were searched. The search terms Nutrient composition, Effect/efficacy supplementation on growth of the “children” OR “adolescents” OR” pregnant women”, Use /Acceptability as food and threats and weaknesses for pearl millet and honey bee brood use. A total of 74 and 42 published articles were identified from the search engines as per the search words on pearl millet and honey bee brood respectively. Similar articles published and identified from different platforms were deleted to include only one while any paper which did not show clear and complete data were eliminated. Only human studies were included while the animal studies were excluded. A total of 39 and 31 papers on pearl millet and honey bee brood respectively were included in the study as shown in figure 1. The resulting articles were analyzed to identify the Nutrient Composition, Effect/efficacy of pearl millet supplementation on growth in humans, Acceptability and Use as Food, Strengths, Threats and Weaknesses for use in a Supplement.

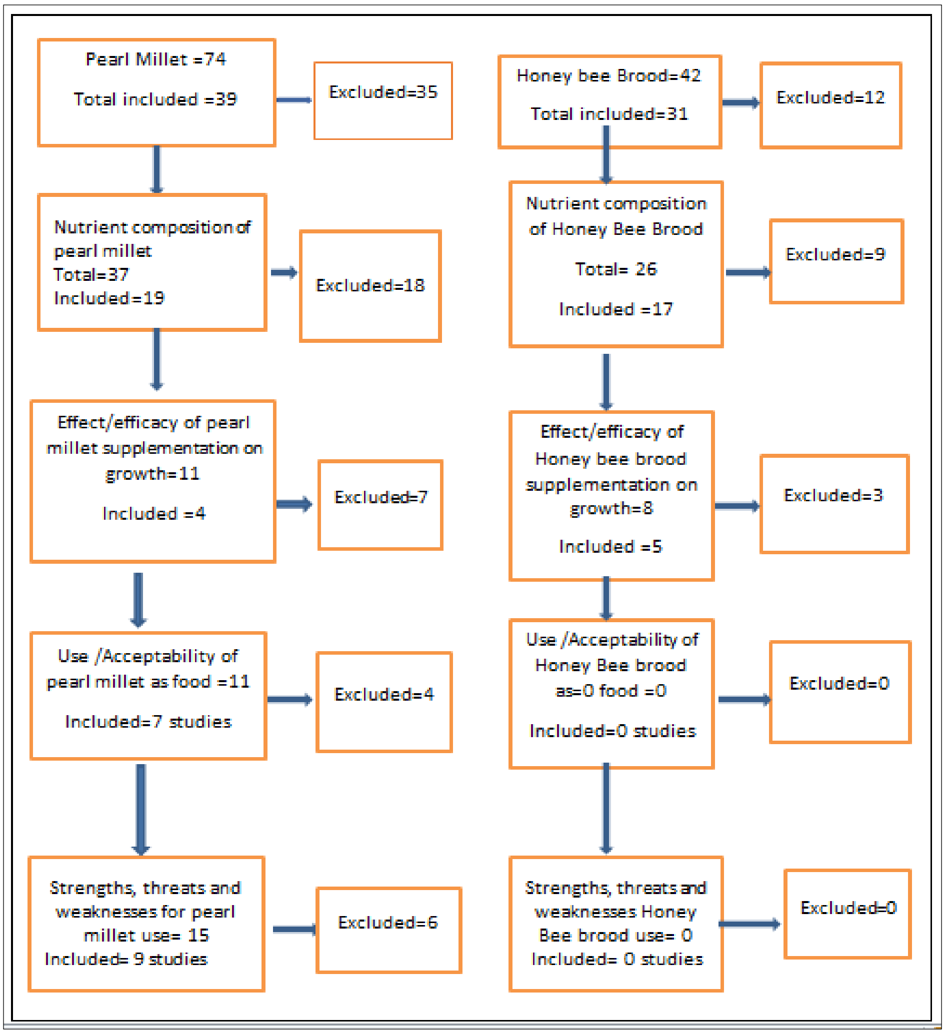

Figure 1: Search words, papers found, included and excluded papers

3.0. FINDINGS AND DISCUSSION

3.1.1 Nutrient Composition of Pearl Millet

Pearl millet is energy dense at 361 Kcal which higher than 346 Kcal in rice, 345Kcal in wheat, 125 Kcal in maize and 349 Kcal for sorghum (Gopalan 2003; Hulse 1980; USDA/HNIS 1984). It is composed of 8 to 21 percent protein (Gopalan 2003; Sade, 2003), as copare to 11.8 in wheat, 6.8 in rice, 10.4 in sorghum, and 4.7 in maize (Gopalan 2003; Abdalla, 1998). The highest amino acids in Pearl millet is leucine at 9.99µg followed by Phenylalanine at 7.65 µg, isoleucine 4.59 µg, and lysine 4.02 µg (per 100g) among others. The high essential amino acids content qualify pearl millet for classification to foods with high chemical score (Mibithi-mwikya, 2000).

The carbohydrate contents in different varieties of Pearl millet is reportedly 58 to 70.5% (Lestienne, 2007; Abdalla, 1998). Unique starches making up the carbohydrates include 20-21.5% of amylose and 1.2 to 2.6 % soluble sugar (Lestienne, 2007). It also contains 2% fibre (Sade, 2009). It is composed of 3.5 to 7.8 percent crude fats (Ragaee, 2006; Gopalan 2003). This is higher than 1.7% in rice and 0.7% in wheat (Ragaee, 2006). Further analysis, indicate contents of 75% unsaturated fatty acids with 46.3% linoleic acid (Jaybhaye, 2014). In other studies, it contain a ash value of 1.6 to 5.9 (Sade, 2009; Adeola 1995; Abdalla, 1998; Gopalan, 2003). It is a good source of vitamins with 0.38mg of thiamine, 0.21 mg riboflavin, 2.8 mg of niacin (Hulse, 1980), 2 Vitamin E, 45.6 (Yadav, 2014; Sade, 2009; Lestienne, 2007)and (micrograms µg/100g) 10–80 for calcium, 450–99 of potassium, 180–270 magnesium, 70–110 potassium, 4–13 sodium, 53–70 zinc, 18–23 magnesium, 10–18 copper , and 70–180 iron (Abdalla, 1998; Gopalan 2003; Sade, 2009). The Dietary cation-anion difference is estimated at 3034mEq/kg (Gopalan 2003). It is also reported to have 2.0% fiber (Sade, 2009).

3.1.2 Effect/Efficacy of Pearl Millet Supplementation on Growth in Humans

Pearl millet has been shown to prevent malnutrition. Apart from the discussed high nutritional value, pearl millet possesses pro-biotic potential which is useful in modulating gut microbiota in malnourished children hence alleviating malnutrition (Blanton, 2016). In a different study, under-nutrition was significantly reduced in adolescent children in Karnataka state in India (Anitha, 2019). Other studies in India have identified that pearl millet-based meals could reduce iron deficiency anemia (Finkelstein, 2015, Rati, 2014). In other studies pearl millet possess health and nutritional benefits when consumed regularly with potential to improve levels of hemoglobin and calcium retention (Anitha, 2021). in a study to determine efficacy for pearl millet in treating acute malnutrition, children fed on pearl millet gained more height (79.2 +3.5) as compared to children fed on maize flour(76.4+7.7),with $p<0.016$ (Ndiku, 2017).

3.1.3 Acceptability and Use of Pearl Millet as Food

Pearl millet is produced worldwide and equally accepted as food. Various studies show that products developed from pearl millet are accepted for food from various parts of the world. (Patil, 2014; Sehgal and Kawatra, 2007; Anitha, 2019; Singh, 2012). Pearl millet is presented as a versatile ingredient, consumed in various forms such as pouridge, cakes, biscuits among other. (Anitha, 2021; Finkelstein, 2015; Rati, 2014; Ndiku, 2017).

3. 1. 4 Strengths, Threats and Weaknesses for Pearl Millet Use in a Supplement

Other than the discussed pleasing nutritional profile, pearl millet require little rainfall to thrive. It is shown to thrive and yield even with rainfall below 300 mm as compared to 600 mm for maize (Léder, 2004; Vadez 2012). Additionally, in comparison to Maize, rice, sorghum and wheat, pearl millet has advantages in terms of cultivation costs, drought resistance, harvesting days, and vulnerability to pests and diseases (Rathi, Kawtra, & Sehgal, 2005; World Bank, 2006). Moreover, it is versatile and can be consumed in many forms by both adults and infants (Amadou, 2016; Saleh 2013). It is also gluten free and has a low glycaemic index.

However, pearl millet contains Anti-nutritional factors which limit protein and starch digestibility, and also bioavailability of minerals (Boncompagni, 2019; Kodkany, 2013; Ouattara, 2006; Abdalla, 1998). In other studies, C-glycosylflavones and polyphenols, have been identified in pearl millet and linked to be giotorgenic problems (Gaitan1989; Boncompagni, 2019). However, studies show that simple processing will cause localization of the minerals, reduce the antinutrients and the gotorgenic components in pearl millet significantly (Nithya 2007; Hassan 2006; Sade 2009; Arora, 2011; Pushparaj and Urooj 2011; Kindiki 2016).

3. 2.1 Nutrient Composition of Honey Bee Brood

The biochemical compositions of honey bee brood differ depending on the various stages of life cycle, (egg, larvae, pupae, and adult forms), as well as the type of the bee (worker, drones). In most studies, honey bee brood is reported to contain 35-57% protein dry weight (Omizek,1985; Finke, 2005; Kim, 2018; Ghosh, 2020; Gahukar, 2011; Rumpold & Schlüter, 2013). This is an equalant conents in in beef, pork, chicken, and egg (40.5 27.7, 54.7, and 52.7 percent) respectively (USDA, 1995). Significant amount of 17 amino acids have been identified where 40-45.9% and 54.1 -59,7% of the total protiens are essential and non-essential amino acids respectively (Ozimek 1985; Finke, 2005; Ghosh 2016; Gosh, 2020; Kim, 2018; Gosh, 2021). This distribution is relative to soybean, which contains 41 and 59% essential and non-essential amino acids of total proteins respectively. The highest essential amino acid in Honey bee brood include leucine at 7.99g/100g; Arginine at 5.20-6.40g/100g and Isoleucine (5.00-7.65g/100g), and Histidine at 2.24 g/100g (Olaleye 2017). In other studies, the total essential amino acids with histidine in honey bee brood is 45.5 which is comparable to 51.2 in egg, 50.4 in cow's milk and 47.9 in beef (Adeyeye, 2012).

The honey bee brood is an excellent source of balanced fatty acids with a composition of Mono unsaturated fatty acids (MUFAs), saturated fatty acids (SFAs) and poly-unsaturated fatty acids 9PUFA) in the ratio of 54: 41: 3 percent respectively. The fat content in honey bee brood is reported as 14.5-20.3% (Ghosh 2016; Ozimek, 1985; Finke, 2005; Gosh, 2020), with dominance of oleic acid (44%) and palmitic acid (30%,) (Chakravorty 2011). Gradual decrease of total fatty acid is reported upards across developmental stages of the honey bee (Gosh 2016; Gosh 2020).

Honey bee brood contains a relatively high value ash. One study determined that the ash value of Honey bee brood is 2.160 ± 0.202% (Chakravorty 2011), which is higher compared to meal bugs crickets and ants, (Adeduntan, 2005). Such ash value is an equivalent of other insects such as termites, tree hoppers, grasshoppers, and almost similar to meats or meat products (Ouasem 2009). Honey bee brood is a rich source of Sodium, Manganese, Phosphorus, Calcium, Zinc, Potassium, Copper, magnesium, iron, and (Chakravorty 2011).

3. 2.2 Use and Acceptability of Honey Bee Brood for Food

Honey bee is among the insects which are commonly used for food worldwide (Kumar, 1998, Finke, 2005, Oonincx, 2010). Honey brood consumption as food for human is a culturally and regularly accepted among many communities in different countries worldwide. Adults and children alike often consume the entire contents of the hive including the bee brood (Crittenden, 2011). However, others do not consider it to be culturally acceptable. Different preparation methods are used including, drying, fraying, and canning, giving it a nutty flavour, or a crunchy taste (Conrad, 2018).

3. 2.3 Effect of Supplementation with Honey Bee Brood on Growth

Little is documented on use of honey bee brood as a supplement. On searching published literature, the researcher found no documented study showing effects of its consumption on growth.

3. 2.4 Strengths, Threats and Weaknesses for Honey Bee Brood Use

Beekeeping requires little input, labour, land and does not rely on nature of soil. In Kenya, beekeeping can be carried out successfully in 80% of the country, including ASALS where crop agriculture is difficult (Government of Kenya (GoK), 2008, Hussein, 2001). Honey bee brood are highly nutritious, and considered a delicacy as presented earlier (Guiné, 2021, Dion-Poulin, 2021). Particularly, it is rich in protein (including essential amino acids), fat carbohydrates, vitamins and minerals (Gosh 2021). Since removal of brood combs is a considerable way to enhance maintenance of the hive, and control of bee hive pest (*Varroa destructor* mite) (Anderson, 2000), honey bee brood is a product on increase and is readily available.

There is low bee faming in Kenya where the coverage and production is only 20% of demand and expectation (GOK, 2008). Honey bee brood is described as very fragile, thus being susceptible to easy rupture (Conrad, 2018). Removing honey bee brood from the comb is not easy though previous studies have tested and commended techniques for removal of the bee brood without breaking or compromising their quality, (Jensen, 2019). The honey bee brood easily becomes rancid due to rapid oxidation when exposed to oxidation.(Taylor & Francis, 2016).

3.3 Nutritive Potential in Informing Potential for Malnutrition Prevention and Resolution

As discussed, Pearl millet and honey bee brood are both energy dense with high protein, fats and micro-nutrients. This gives an advantage of smaller portions for the consumer to achieve the recommended daily allowances. Pearl millet is high in leucine, Phenylalanine, isoleucine, and lysine while Honey bee brood is high in leucine, Arginine and Histidine (Olaleye 2017). Presence of these Amino acids in high proportions are beneficial alleviation of muscle wasting and weight gain. While the daily requirements of Essential Amino Acid with Histidine (g/100g, with Histidine) are 46.0 in infants and 33.9 for pre-school (ages two to five years) children (FAO/WHO/UNU, 1986), Pearl millet and honey bee brood are able to contribute all to requirements in less than 100g of each. Hence the two can be formulated to meet the daily requirements at reasonable amounts.

Leucine administration at a rate above 150mg/kg per day is evidenced to activate protein synthesis in the muscle induces protein synthesis (Tessari ,1987; Giordano, 1996, Glynn, 2010.; Rieu, 2006; Blomstrand, 2oo6) and also reduces muscle degradation in humans (Nair 1992, Ferrando, 1996, Wamiti, 2018; De Bandt, 2006). Honey bee brood has a high potassium to sodium ratio of 350:1 (Finke, 2005). This is an important ratio, essential for fluid and electrolyte level balance, proper nerve transmission, and muscle function which are affected in under-nutrition (Treasure, 1983; Houston 2011; Raza 2020). Honey bee brood also pose a high calcium source as it contains about 1.2 mg per 100 g (Chakravorty 2011).

4.1 CONCLUSION AND RECOMMENDATION

4.1.1 CONCLUSION

Both pearl millet and honey bee brood are accepted and consumed worldwide as food. Pearl millet is contains high calorie, and balanced micro-nutrients. On the other hand, honey bee brood is rich in protein, fats, vitamins, and minerals. Combining the two in conventional diet would provide adequate nutrients for humans. Since they are energy dence, complemented by balanced amino acids and micronutrients, the two can be promoted for malnutrition prevention and resolution in the arid and semi-arid lands where they are produced.Though some studies show that pearl millet contain anti-nutrients, C-glycosylflavones and polyphenols, others indicate that these are significantly reduced by simple processing and cooking. On the other hand, though removing honey bee brood from the comb is not easy and that honey bee brood easily becomes rancid when exposed to oxidation, studies have indicated simple methods of processing, making it easy for uncapping and preventing rancidity.

4.1.2 Recommendations for Further Research

The following further research is suggested:

1. Explore the development of honey bee brood and pearl millet-based supplements food.
2. To perform efficacy testing for honey bee brood and pearl millet supplementary foods
3. To conduct studies on commercialized production and processing of Honey bee brood

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