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Research Article

Viability of Cull Bee Brood (*Apis mellifera*) as an Additive in Chicken Feed for Enhanced Food Security

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Abstract

There is insufficient knowledge by African beekeepers on how to utilize and integrate culled bee brood into their chicken feed or food systems instead of dumping broods as wastes. Culling out access bee brood combs, diseased, old combs with brood remains will reduce over reproduction of bee brood in the bee colony and hence improving hygiene in bee hive colony which will increase its fitness. African bee keepers regularly practice bee brood culling of unwanted, damaged, diseased and excessive combs with brood during production and harvesting periods and throw away culled bee brood Africa beekeepers. Therefore, this study came up with new ways on how to collect, process, utilize and integrate culled bee brood into chicken feeds as additives instead of throwing them away as wastes. This would create new production opportunity among bee keeper now and in the future as culled bee brood to be an alternative source of protein in chicken feeds systems leading to improved food security. The study was conducted in three districts of southwestern Uganda (Kiruhura, Mbarara, Rwampara). Current Nutritional composition and hygiene practice were analyzed after sampling practices and collection. Analyzed 966 culled bee brood combs from 46 beekeeper's colony. Data was analyzed using r-statistical program. All assumptions for statistical tests were met. A total of seven (7) apiaries participated in cull brood removal sample from 46 bee hives from each district that was sampled making a total of 966 colonies. a repeated measures ANOVA both at beginning of the season and the end of the season was used to analyze the beekeepers' data from different apiary yard in western Uganda and five (5) colonies (bee hive) from an on-farm trial experiment at Mbarara, Kiruhura, Rwampara western Uganda, three (3) treatment and two control were utilized. Repeated measures ANOVA was used to analyze this data. Using computer aided software of R-statistical package for analysis. Results were presented in table form from different seasons from laboratory analysis. The study also adds to existing literature where some insects are used industrially for selling as seen with the Nsenene (grass hoppers) in Uganda and crickets and black soldier's flies in western Kenya at Jaramongi Odinga Oginga University of Science and Technology. MP2 has the highest metabolizable energy with slightly less microbes, and average moisture content. This makes it a good choice of feeds with bee brood additives for the chicken.

Keywords

Viability, Cull Bee Brood, An Additive, Chicken Feed, Enhanced Food Security

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1. Introduction

A high human population especially in the rural areas of developing countries cannot afford the basic necessities of life for example food. Insects hold enormous potential to address food and nutritional security issues, especially in African countries where the eating of insects is a common practice with each type having its own taste, scent and texture [1]. Generally, insects are more ecologically reared meats because they produce lesser amounts of greenhouse gases, and require fewer resources when produced on their current scale. Edible insects are commonly utilized within developing countries [2], meaning that edible insects are easily accessible to a large range of people when collected from the wild. Insects that are consumed are often an abundant in sub African region and since insects use few resources, they are also often abundant in given area even in times of drought or harsh climates [2].

There are over 2,111 edible insect species worldwide [3] and while collecting from the wild may not be sustainable for the population of insects [1], they are accessible to almost everyone in some way, shape, or form, therefore, edible insects outweigh traditional meats in terms of sustainability, and the opportunity to diversify the protein markets stated above, people often consume insects that are abundant, such as crickets or beetles.

One insect that is uncommon to eat is *Apismellifera*, also known as the Honey bee. Beekeepers will provide culled bee brood combs for processing in order to formulate cull bee brood additives from both active colonies and old off stock bee hive. Raw bee culled brood are soft or raw drone larvae or pupae are soft [4]. The honey bee (*Apismellifera*) is an important insect not only for its products which can be directly consumed, like honey, pollen and brood but also for pollination [5].

In beekeeping, brood refers to the eggs, larvae and pupae of honeybees. The brood of honey bees develops within a bee hive. In man-made, removable frame hives, such as Langstroth hives, each frame which is mainly occupied by brood is called a brood frame. Brood frames are composed of brood at various stages of development-eggs, larvae, and pupae. Brood frames usually have some pollen and nectar or honey in the upper corners of the frame. The rest of the brood frame cells may be empty or occupied by brood in various developmental stages. There is only one reproductive in the hive the queen. She lays egg per cell, gluing it to the bottom. The queen tends to lay brood in circular or oval pattern. At the height of the brood laying season, the queen may lay so many eggs per day that the brood on a particular frame may be virtually of the same age [4]. During the season, the bees may reuse the cells from which brood has emerged for additional brood or convert it to honey or pollen storage. Bees show remarkable flexibility in adapting cells to a use best suited for the hive's survival [4]. As the egg hatches, worker bees add royal jelly - a secretion from glands on the heads of young bees. For three days the young larvae are fed royal jelly, and then they are fed nectar or diluted honey and pollen. Young larvae eat their way through the royal jelly in a circular pattern until they become crowded, then they stretch out lengthwise in the cell and their older sisters' bee seal the cell with a wax lid soon after they begin to spin a cocoon, they go into the pupa stage. These cells collectively are called "capped brood." [4]. Honey bees (*Apismellifera*) are an insect found on every continent except Antarctica. They have an intricate social organization, living together in colonies. Each colony contains one fertile female queen, at least 20,000-80,000 infertile female workers, 200-300 fertile males, also known as drone [6]. Each bee plays a specific role in the colony: queen lay the eggs for the colony; worker bees perform most of the colony's activities. There are a number of roles worker perform that is the nurse bees who feed brood, foragers who leave the colony to collect nectar and pollen, guard bees who protect the colony against intruders threats, brooders which assist in raising brood, and comb repairers who help fix comb within the hive [7, 8]. The success of a colony depends on how well the social structure of the colony works. Honey bees have four life main cycle stages: egg, Larvae, pupae, and adult [7, 9].

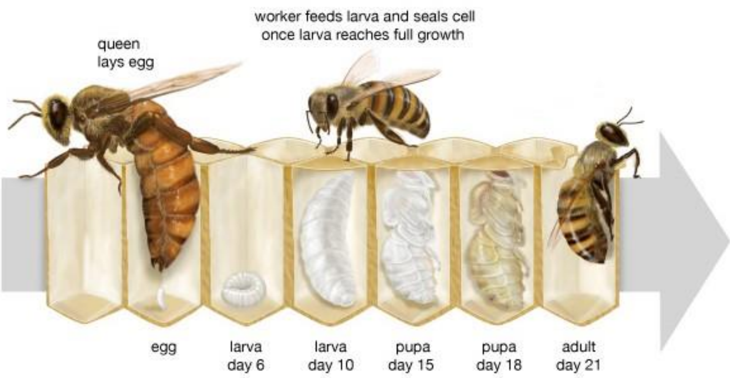

Figure 1. *Life cycle of honey bee.*

Eggs are laid by the queen and will develop into that larva will spend the majority of their time eating; once the larval cell is covered with a wax capping they undergo five molts [8]. After approximately 20 days, the bee emerges as an adult [8]. The entire cycle takes 21 days for workers, 24 days for drones, and 16 days for queens [8, 10]. The life span upon emerging varies based on the time of the year and food resources available. Worker bees live for 15-40 days here in tropics environment. Drone lives between 21-32 days and queen live between one-three years (1-3) years [8]. The honey bee life is well described and important in understanding the function of a honey bee colony.

Honey bees are one of the most significant pollinators [8, 10, 13]. Pollination of flowers occurs during the collection of pollen and nectar. Pollen is often collected from flower stamen, and nectar from floral nectarines [8]. Honey bees are generalist pollinators [13], pollinating more than one third of commonly consumed foods [14]. Since honey bees are widespread throughout the world, plants they pollinate will change based on the area. It has been estimated that the value of honey bee pollination on crop yields is $ 9.3 billion [16]. Honey bees are an important commodity for food security, providing humans with a source of food and income. Honey bee decline can significantly affect the pollinating economy; Beekeepers may rent out their bees for pollination services. During the night, beekeepers will move colonies to agricultural land such as pumpkin patches, apple orchards, leave the bees for few days and then take the bees back to their apiary [17]. An increase of commercial pollination in the 1950's led to an increase in beekeeping during this time [7], thus allowing the bee keeping industry to begin flourishing. In 2005, the economic value of insects' pollination was estimated at $246 billion, with a total of 84% of crop species depending on insect pollinators, specifically honey bees [18].

Honey bee (*Apismellifera*) larvae have a valuable nutritional composition of proteins, fatty acids, vitamins and minerals [19, 21]. Honey bee brood is a versatile ingredient in the kitchen. It can be used whole or blended, and can be processed using wet or dry heat, acid or fermentation techniques [22]. Usage of bee product for human consumption in Denmark is currently in use [11], as food but this study will look at use of bee brood as chicken feed additives in Africa as new enterprises.

Bee brood is harvested by beekeepers in many countries in Africa with other bi-products but dumped away as waste because African beekeepers look at brood as waste, hence they don't utilize them in any way; the pupae are the highest in protein when compared to the eggs and larvae, and have protein content equivalent to that of beef or poultry [10]. Brood is rich in carbohydrates, dietary minerals, B vitamins, vitamin C, vitamin D, saturated fat, monounsaturated fatty acids and polyunsaturated fatty acids [10].

Protein sources are the additional main constituent of protein additive of poultry feeds in the livestock sector [13]. In some of these cases, insert species are collected from the wild because they are high an abundance [12, 23] or because they are a pest insect [3]. Regardless, some insects are used industrially for selling as seen with the Nsenene (grass hoppers) in Uganda [21]. Crickets and black soldier's flies are reared in western Kenya at JOOUST [11]. These farms introduce the East African Region to edible insects, specifically by processing insects into products that consumers are familiar with, such as proteins or foods or cookies in form of cricket biscuits. JOOUST farm creates these products hoping that consumers will become more receptive to edible insects, which ultimately helps to reduce the negative attitude around edible insects.

Honey bee brood is often consumed in Thailand due to its high abundances [24], but in East African Region bee brood are eaten local but not officially documented.

In addition to being used due to availability, honey bee brood are also a good source of amino acids [24], containing around 30milligram of calcium, 18.5 milligrams of iron,10.25 milligrams of vitamin A [25]. There is needed to take samples of different bee cull brood from different regions of Africa in order to carryout analysis. Use of bee brood is noted that it has been used as human food as early 1990's, although methods of utilization are laborious (Graham, 2015). Within this objective the use of curl brood as edible insects will be explored.

The scarcity of additive rich in protein have created challenges of feeds scarcity and malnutrition in the livestock sector [26]. This is attributed to scarcity of this additive on a commercial scale and in communities where these farmers are based [26]. Fewer efforts have been put in place to bridge the scarcity gap. Culled bee brood has been identified as one of the sources of protein additives in poultry farming [27]. Available evidence indicates that honey bee brood has high content of carbohydrates and protein, as well as essential amino acids [28]. Brood is a good source of phosphorus, magnesium, potassium and the trace minerals iron, zinc, copper, selenium and most of the B-vitamins, as well as vitamin C and chlorine [19]. The fat content provides a balanced composition of saturated and mono-unsaturated fatty acids with only about 2.0% being polyunsaturated fatty acids [28]. When fed on poultry, bee brood helps the chicken to grow faster than when fed on any other additives [27].

In Uganda, bees are mainly known as source of honey by farmers in rural communities [29]. A few people, use bee brood as a source of food and more so for feeding poultry as an alternative source of proteins [29]. Protein is one of the main compartments of poultry feed and is one of the major contributors to the finished feed cost, yet it is the scarcest component to farmers in the country [26]. However, bee brood is thrown by most, if not all farmers in Uganda after harvesting honey in Uganda [30]. Research on bees in Uganda and East Africa in general is mainly centred on honey as a main product and their role on pollination agriculture [31]. There is insufficient knowledge by African beekeepers on how to utilize and integrate culled bee brood into their chicken feed or food systems instead of dumping broods as wastes. and hence improving hygiene in bee hive colony which will increase its fitness. Since African bee keepers regularly practice bee brood culling unwanted, damaged, diseased and excessive combs with brood during production and harvesting periods and throw away culled bee brood in Africa.

2. Materials and Methods

2.1. Nutritional Composition and Nutritive Value Analysis of Broods (Egg, Larvae and Pupae)

The Kjeldahl method [18] (the industry standard test used to routinely measure the crude protein content of foods) measures the total nitrogen content of a food, which is then used to estimate the crude protein content by applying a conversion factor to the result., and the Soxhlet extraction method uses a Soxhlet extractor as an extraction apparatus, and is extracted by refluxing with a low-boiling organic solvent (ether or petroleum ether) to remove crude fat in the sample, and the crude fat content was calculated by the difference between the weight of the sample and the residue and expressed in percentages:

$$\%\mathrm{CF} = \frac{\text{dry weight of residue before ashing} - \text{weight of residue after ashing}}{\text{eight of sample}} \times 100$$

Nitrogen free extract (NFE) and Metabolizable energy (ME) will be calculated according to procedure of Pauzenga (1985) as;NFE % = %Dry matter- (Crude Fibre + crude protein + ether extract + ash)ME (Kcal/kg) = 37*Protein (%) +81.8 *Fat (%) + 35.5*NFE (%).

2.2. Mineral Analysis

Carbohydrates, calcium, iron, manganese, and zinc, copper was analyzed by alpha 4 atomic absorption spectrophotometer. Sodium and potassium was estimated by flame photometry.

2.3. Amino acid Analysis

Processed and preserved culled bee brood additives was profiled for essential amino acid (lysine, methionine, cysteine, trytophan) according to the [32] in a biochrom 30-amino acid analyzer.

3. Results and Discussions

The chemical composition and nutritive value of the cull bee brood samples as an additive Metabolizable Energy (ME) and Nitrogen Free Extract Energy (NFE) Table 1.

Table 1. *Results of chemical composition and nutritive value of the culled bee brood samples as an additive metabolizable Energy (ME) and Nitrogen free Extract Energy (NFE).*

Contents.	**Carbohydrates Concentration (mg/ml)**	**Protein Concentration (mg/ml)**	**Crude fat (%)**	**Crude fibre (%)**	**Moisture content (%)**	**Total ash content (%)**	**Bacterial load count (*100)**	**NFE**	**ME**
Sample code.									
R P1	3.8408	1.3866	12.2000	0.0473	10.0	16.7153	26	59.6508	3,173.3
R P2	5.1729	1.7271	22.3333	0.0212	4.5	23.2233	3	48.1951	3,645.6
R P3	3.5530	1.2864	26.0667	0.0125	12.2	16.7750	36	43.6594	3,788.8
R2 P1	3.7828	1.5688	11.3000	0.0367	6.5	15.5153	16	65.0792	849.6
R2 P2	3.8159	1.3866	21.7000	0.0241	5.0	21.5700	7	50.8146	3,671.5
R2 P3	2.9526	1.2996	19.5633	0.0129	10.0	15.6943	26	53.4299	1,935.1
R LAVEA	5.7414	2.9755	20.1667	0.6100	13.0	21.0747	82	42.1731	3,294.4
R2 LAVEA	4.4371	2.9121	19.9500	0.4370	16.0	19.1500	100	41.5509	3,252.0
M P1	3.0975	1.0251	18.0333	0.3257	9.0	21.0700	20	50.5459	3,337.8
M P2	1.5261	1.3127	24.5000	0.0025	11.0	18.6787	29	44.5067	4,036.2
M P3	1.2010	2.4186	14.3000	0.0353	7.0	17.5880	8	58.6581	3,283.2

Contents.	Carbohydrates Concentration (mg/ml)	Protein Concentration (mg/ml)	Crude fat (%)	Crude fibre (%)	Moisture content (%)	Total ash content (%)	Bacterial load count (*100)	NFE	ME
M2 P1	3.1803	1.3602	13.1767	0.3163	9.0	19.1103	20	57.0365	3,163.9
M2 P2	1.4184	0.4550	14.5000	0.0014	9.5	17.4520	22	58.0916	983.5
M2 P3	1.1327	4.0179	12.3667	0.0340	8.0	16.3047	13	59.2767	3,266.5
M LAVEA	1.3232	4.0179	28.4333	0.0053	13.0	20.8623	67	33.6812	3,736.3
M2 LAVEA	1.1803	2.9359	20.9333	0.0044	12.7	16.3760	56	47.0504	3,528.9

Predictable Metabolizable Energy (ME) (kcal/kg) ME = (35x crude Protein + 85 x crude Fat + 35 NFE) NFE (Nitrogen Free Extract) = 100 - (Misture + Crude Protein + Crude Fat + Crude Fibre + Ash) from table 1. nutrition composition.

Graphical Representation of Percentage Content of Bee Brood Feeds Figure 2.

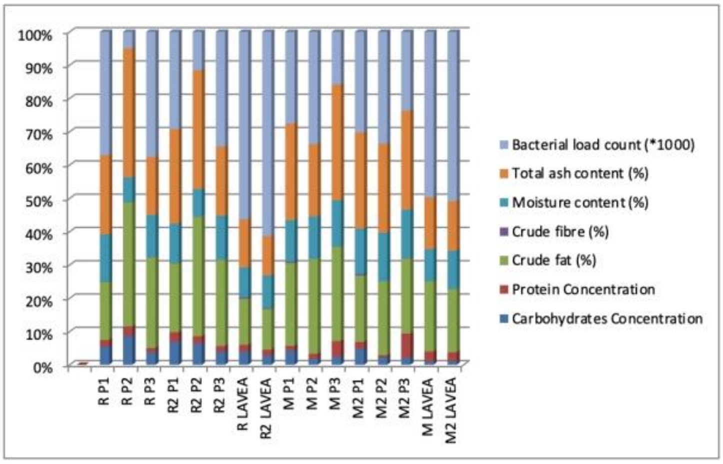

Figure 2. *Protein content composition.*

R LARVAE – Highest carbohydrate content. M2P3 and M2P2 – Highest protein content. M LARVAE – Highest crude fat content. R2 LAVEA – Highest bacterial content. RP2 – Lowest bacterial content. RP2 – Lowest moisture content from Figure 2 protein content composition.

Graphical Representation of Predictable Metabolizable Energy (ME) Figure 3.

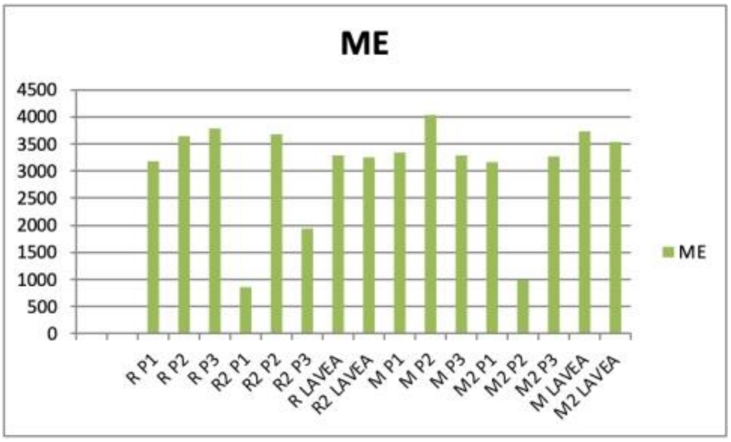

Figure 3. *Predictable Metabolizable Energy (ME).*

MP2 – Highest metabolizable energy. R2P1 – Lowest metabolizable energy. MP2 has the highest metabolizable energy with slightly less microbes, and average moisture content. This makes it a good choice of feeds for the chicken. RP2 has the lowest microbes with a high metabolizable energy and lowest moisture content. This makes its shelf life on storage high, and also minimizing the risk of transmitting bacteria to the chicken figure 3.

4. Conclusion

MP2 has the highest metabolisable energy with slightly less microbes, and average moisture content. This makes it a good choice of feeds for the chicken. The average moisture content also enhances its shelf life on storage. The high concentration of metabolisable energy provides nutrients in its lowest dosage form, thus less sample required during feeding of chicken, which makes it economically effective.

This study on the chemical composition and nutritive value of cull bee brood as an additive have shown that cull bee brood is rich source of protein, vitamins, minerals, and essential amino acids. The composition of cull bee brood can vary depending on the species of bees, age of the brood, location and the diet of the colony. RP2 has the lowest microbes with a high metabolisable energy and lowest moisture content. This makes its shelf life on storage high, and also minimizing the risk of transmitting bacteria to the chicken. Therefore, it is the best choice; since it lowers the risk of infecting chicken in addition to providing high metabolizable energy.

Cull bee brood has been found to contain high levels of protein, with an average protein content of about 50%. It is also a good source of vitamins and minerals, including vitamins B1, B2, B6, B9, C, and E, as well as minerals such as calcium, iron, and zinc. In addition, cull bee brood contains essential amino acids that are important for growth and maintenance of the body.

5. Recommendations

The average moisture content also enhances its shelf life on storage. The high concentration of metabolizable energy provides nutrients in its lowest dosage form, thus less sample required during feeding of chicken, which makes it economically effective. Therefore, it is the best choice; since it lowers the risk of infecting chicken in addition to providing high metabolizable energy. High moisture content promotes microbial growth; this increases risk of infecting chicken in addition to decreasing the shelf life of the feeds.

This calls for sensitization of farmers by stakeholders involved in promotion of livestock farming in communities such as agricultural extension workers about the importance such alternative sources of protein additives in chicken feed ration. Importantly, farmers need integrate bee keeping with poultry farming in order for the enterprises to help one another.

6. Policy Implications

Use of Viable Cull Bee Brood (*Apis mellifera*) should be utilised as an Additive in Chicken Feed for enhanced Food Security.

Analysis of Culling out access bee brood combs, diseased, old combs with brood remains would reduce over reproduction of bee brood in the bee colony and hence improving hygiene in bee hive colony which will increase its fitness. in the region. Based on the findings and discussions, This calls for sensitization of farmers by stakeholders involved in promotion of livestock farming in communities such as agricultural extension workers about the importance such alternative sources of protein additives in chicken feed ration. Importantly, farmers need integrate bee keeping with poultry farming in order for the enterprises to help one another. This would create new production opportunity among bee keeper now, and in the future as culled bee brood to be an alternative source of protein in chicken feeds systems leading to improved food security.

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Conflicts of Interest

The authors declare no conflicts of interest.

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