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Gross Energy Densities of the Locally-Available, Unconventional Feed Ingredients for Poultry Feeds

Dr. Shabihul Fatma Sayed[1], Dr. Imtiaz A. Khan[2], Dr. Randa Ameen Basheer[3]

[1,3]Jazan University, Kingdom of Saudi Arabia,

[2]Associate Professor, Kashmir University, J&K, India

Running Title: Unconventional feed ingredients

Abstract: ***1. The potential of some unconventional by-products of animal and plant feed industry has been investigated in this study for their possible inclusion as dietary energy supplements in practical animal feeds. 2. The samples were collected during the months of June-August, 2017 and November 2017 to January 2018. The gross energy content of the collected feed ingredients was determined by direct calorimetry using Ballistic Bomb Calorimeter (Gallenkamp, Loghborough, UK). 3. Significant differences (P<0.05) were found in the gross energy density of the collected feed ingredients. The gross energy content of the feed ingredients ranged between 12.8 to 23.7 kJ g^{-1}. 4. On an average, the unconventional feed ingredients of animal origin contained highest gross energy followed by the plant origin feed ingredients and aquatic weeds. 5. The results of the gross energy densities of ingredients showed that all the collected unconventional feed ingredients of animal and plant origin have good potential as energy supplements for animal feeds. The inclusion of these ingredients as cost-effective energy substitutes in poultry feeds will promote commercially viable poultry culture by reducing the incurring cost on practical feeds. 6. Data generated during this study will, therefore, be of high use for the local animal/poultry farmers. Combination of these ingredients can be used as energy supplements which will spare the utilization of protein only for tissue building purposes and limit it for being used as energy yielding nutrient. 7. This would be a way to improve the profitability of poultry farming and make the poultry production more sustainable.***

Keywords: Unconventional by-products, energy density, Ballistic bomb calorimeter

1. Introduction

Terrestrial animal are destined to play an important role in human nutrition but the cost is still beyond reach of many people. They are important source of animal protein and the source of livelihood in most of the parts throughout the world. Health benefits of animal protein are superior over the plant protein, therefore, turning towards animal protein as a healthy source of digestible quality protein supplement is important. Dietary inclusion of animal protein is required in adequate amount in all stages of human life. From infancy to old ages, consumption of protein from animal origin along with a balanced diet ensures a healthy life with minimal susceptibility to diseases.

Among various cultivable terrestrial animals, poultry is present in almost all systems in all parts of the world (Pym and Alders 2012) providing nutritious meats and eggs for human consumption within the shortest possible time. Ultimate goal of any livestock industry is to attain sustainable and cost-effective livestock production so as to give access to animal protein source with minimum cost. However, availability of quality feed at a reasonable cost is a key to successful poultry operation (Basak et al. 2002).

Feed plays an important role in the value chain as economically viable poultry culture system depends only upon a consistent supply of low-cost feeds with high nutritional quality. Lack of affordable feeds is one of the major constraints facing small-scale poultry farmers (FAO 2009, 2012). It is known that the formulation of poultry feed is mainly based on corn and soybeans; however, the availability of these grains is variable, depending on region and time of year, thus leading to variations in the costs of these raw materials, directly affecting the profitability in poultry. Formulated feeds are expensive as most of the ingredients such as soybean meal, fish meal and fish oil which compete with human consumption.

There are a number of unconventional feed ingredients that could be utilized as promising source of feed ingredients. Adopting unconventional ingredient seems to be a logical step for poultry producers, however, prior to inclusion in poultry feeds, the feed formulists must recognize that the unconventional feed ingredient is economical and complements the goals of production system when used in the diet.

In most households and locations, several by-products from cereal milling are available for animal feeding, including bran, hulls and screenings. Despite their high fibre contents, these can be valuable sources of energy. Small and damaged tubers and roots of cassava, sweet potatoes and yams, which are unfit for human consumption, are available in many areas and could be processed into a high-energy animal feed. A number of locally available fruit by-products can be used to provide energy. A good example is banana peels, which can be collected from local markets, sun-dried and milled into a meal, mango seed kernel etc. These materials are good sources of supplemental energy.

Several leaf meals have been studied with respect to their suitability as protein sources by aquaculturists in fish diets. These include leucaena, *Leucaena leucocephala* (Pantastico and Baldia 1980; Ferraris et al. 1986; Santiago et al. 1988), duck lettuce, *Ottelia alismoides*, water snowflake, *Nymphoides indicum* (Patnaik et al. 1991), sweet potato, *Ipomoea batata* (Borlongan and Coloso 1994), alfalfa, *Medicago sativa* (Yousif et al. 1994), water spinach, *Ipomoea reptans* (Borlongan and Coloso 1994), water hyacinth, *Eichornia crassipes* (Hasan and Roy 1994, Hasan et al. 1997), mulberry, *Morus spp* (Vijayakumar Swamy and Devaraj 1995), acacia, *Acacia auriculiformis* (Mondal and Ray 1999), papaya, *Carica papaya* (Eusebio and Coloso 2000; Palavesam et al. 2001), sesbania, *Sesbania sesban* (Hafez et al. 2001), duckweed, *Lemna polyrhiza* (Bairagi et al. 2002) and peanut, *Arachis hypogaea* (Garduno-Lugo and Olvera-Novoa 2008). However, such detailed published work is sporadically available for animal feed industry, mainly the poultry industry.

The gross energy content of feed ingredients is central to accurate feed formulation as it increases the animal performance and minimizes environmental impact. A change in the energy content of the diet will normally result in an inverse change in the total amount of feed consumed and will, therefore, influence the intake of essential nutrients (Slagter and Waldroup 1990). Hunton (1995) proposed that nutrients intake is influenced by different levels of energy in diet.

Data on energy values of feed ingredients are important for nutritional assessment, research linking diet and disease, health and nutrition policies and programs, agriculture policies, food labelling and consumer education. With regard to animal health, proper energy intakes are quite necessary.

Unconventional feed ingredients have to be considered for use in poultry feeds to overcome the short supply of traditional ingredients and to reduce production costs. Massive quantities of industrial by-products are produced everyday and large amount of wastes come from major crop systems (banana, coffee, sugarcane and oil palm) whereas the remainder comes from animal production systems (poultry production and slaughtering industry). The potential use of the major vegetable and animal residues in poultry feeds is based on their nutritional composition and the energy density. The most interesting wastes which are rejected are green banana and coffee pulp.

It is, therefore, important to look for potential unconventional energy sources of plant and animal origin for inclusion in poultry feed. Hence this study was conducted to explore the energy density of the unconventional feed ingredients so that they may be utilized in poultry feeds as nutrient rich ingredients.

2. Materials and Methods

2.1 Collection of feed samples

Samples were collected during a period of 3-months (November 2017 to January 2018) from local markets of Farasan, Jazan, KSA, and from typical locations and local markets in New Delhi, during the months of June to August (2017). The collected feed ingredients were broken-grains, oil cakes, pulse dust, brans, bakery by-products, fruit peels and various others that are listed and their localities are presented in Table 1. Wheat middlings were collected from city market of New Delhi. Samples of feed ingredients collected were packed in polythene bags to prevent initial spoilage and brought to the Biology laboratory, Jazan University, KSA. The collected samples were sterilized in an Autoclave under solid sterilization cycle (Maxterile 47, Daihan Scientific, Korea) and then kept at 80°C in a hot air oven (DOV 53 A, Beijing KWF Sci-Tech Development Co., Ltd.) for drying to constant weight prior to subject for gross energy estimation. The samples were then ground into finer particles using an electric grinder and sieved through a 100 µm sieve.

2.2 Collection of live feed samples

The cockroach (*Periplaneta americana*) and earthworms (*Lubricus terrestics*) were collected from Agricultural fields near New Delhi. Fifty grams of each specimen were washed in distilled water, oven dried at 60°C for 24 h., ground to fine powder and stored in a polythene bags for subsequent energy estimation.

2.3 Gross energy estimation

Screening large numbers of feed ingredients for the gross energy content (GE) requires a fast and reliable method. Gross energy content of the collected feed ingredients in this study was estimated using Ballistic Bomb Calorimeter (Gallenkamp, Loghbrough, UK).

2.4 Sample preparation

The representative samples of the feed ingredients were ground and sieved through a 100µm mesh screen and again dried at 50°C overnight. Gross energy density was determined by using ballistic bomb calorimeter. 1.0g sample was taken in a metallic crucible. The sample was compacted carefully using the tamping tool and ignited in the bomb filled with oxygen. The heat released was read on a galvanometer. Quadruplicate determinations were made for each sample. Calorific values of subsamples were averaged and expressed in kJ g^{-1} dry weight of the sample (Miller and Pyne 1959).

2.5 Calibration of the instrument

0.7 g of benzoic acid (BA) is ignited and the energy released is read on a galvanometer. This is used in calibrating the instrument. It was dried at 125°C to a constant weight prior to calibration.

2.6 Statistical analysis

The gross energy determination of the ingredients was done in quadruplicate. The results from the replicates for each feed ingredient were used to provide the data for the statistical analysis and expressed as mean±SD. Differences among treatment means were determined by Tukey's significant difference test at a $P<0.05$. All the statistical analyses were done using Origin (version 6.1; Origin Software, San Clemente, CA).

3. Results

The estimated gross energy contents of the 34 collected unconventional feed ingredients of plant and animal origin are summarized in Table 2 and 3. The calorific values of the analysed feed ingredients as gross energy indicate considerable variation in the energy density of the feed ingredients. The analysed gross energy density of goat liver meal (23.7 kJ g^{-1}) was significantly higher ($P<0.05$) than the gross energy density obtained for blood meal (19.8 kJ g^{-1}). However, significantly lowest ($P<0.05$) gross energy density was obtained for earthworm meal (12.8 kJ g^{-1}). Among the weeds with the exception of algae, the gross energy density ranged between 14.5 to 16.03 kJ g^{-1}. On an average, the unconventional feed ingredients of animal origin contained relatively higher energy density (16.4-23.7 kJ g^{-1}). Brans with gross energy density 17.6-17.8 kJ g^{-1} came next to the feed ingredients of animal origin.

Based on the data on gross energy analysis of the selected unconventional feed ingredients presented in Table 2 and 3, 4 feed ingredients of animal origin and 34 feed ingredients of plant origin were identified as promising energy sources for inclusion in poultry feeds. On the basis of the results of the gross energy density of the unconventional feed ingredients, the ingredients analysed in this study are categorized as under:

3.1 High energy feeds (Animal origin)

These include the blood meal, goat liver and the chicken viscera. These are the good and cost-effective energy sources for formulated poultry feeds.

3.2 Low-energy feeds (Animal origin)

The earthworm meal due to its lowest energy density among the animal by-products is considered under this category. The low-energy density may be due to lot of mud present in their gut.

3.3 High energy feeds (Plant origin)

Brans such as wheat and rice brans due to the presence of oil exhibited higher values for the gross energy and hence put under this category. These may be used as cost-effective, unconventional source of energy in poultry feeds.

3.4 Low-energy feeds (Plant origin)

The algae and weeds were grouped under this category. Inspite of having low energy, they can be successfully utilized in the practical feeds of poultry.

4. Discussion

The high and rising cost of commercial feed based on imported ingredients is the major constraint in poultry production. The key strategy to mitigate this is to substitute imported feed grains with locally available alternatives. Agro-industrial by-products are an important local source of feed resources and their effective utilization, particularly in poultry, pig and pond fish diets, will lead to more affordable livestock feed for smallholder farmers. A wide variety of unconventional feed ingredients is available throughout the world including KSA and in India. Some of the ingredients from the animal byproduct industry that may become the potential energy supplements in aquaculture feeds include blood meal, intestinal meal and various others. The potential of these by-products as ingredients in poultry feed formulations lies in their local-availability, affordability and relatively good nutritional profile.

Protein, the most expensive component of feeds, plays an important role in growth of poultry. The utilization of dietary protein is related to both protein level and availability of non-protein energy sources. Increasing cost and unavailability of commonly used feed ingredients in poultry culture is increasing the production cost of poultry. Hence, there is need to find out sources of unconventional feed ingredients that could be used in preparing cost-effective poultry feeds.

Inclusion of non-protein energy sources has been shown to lower dietary protein used for energy and increase protein utilization for growth, a process known as protein sparing (Morais et al. 2001). It may be attributed that the higher energy density and hence the nutritive richness of the unconventional feed ingredients of animal origin may be due to their higher organic matter. Similarly, higher inorganic content in the plant origin feed ingredients may be responsible for their low gross energy densities. However, variations in the gross energy densities of the animal origin unconventional feed ingredients may be seen which may be attributed to a number of extrinsic and intrinsic factors (Jana and Pal 1980).

In this study various unconventional feed ingredients were analyzed for their gross energy content. Unconventional feed ingredients such as cattle blood is an abattoir by-product that directly affects the environment. Most of the blood from a considerable number of slaughter house is wasted, not efficiently utilized, and pollutes the environment on a daily basis (Adeniji 1995; Makinde 2006). Paradoxically, bloodmeal, obtainable from cattle blood after drying, contains 80-90% crude protein high in the essential amino acids, especially lysine (NRC 2011). The ingredient analysis in this study revealed that blood meal contains an energy density of 19.8 kJ g^{-1} and hence is an important utilizable source of energy supplement in poultry feeds.

The lower energy density of the earthworm meal (12.8 kJ g^{-1}) obtained in this study may probably be due to lot of mud in the gut. However, the calorimetric determination of this unconventional feed ingredient indicates that it is a potential energy supplement which could be utilized in practical poultry feeds.

Similarly, bakery by-products may also serve as a primary energy source in poultry feeds. They are obtained from baking and cereal industries. Dried bakery by-products are composed of a variety of commodities, including hard and soft wheat products, pasta, potato chip waste, cakes, crackers, breakfast cereals and other food products. Bakery products are high in fat and carbohydrates and are an excellent source of energy. Bakery byproducts are one of the few unconventional ingredients that can increase the energy content of the diet when compared to corn with energy profiles as much as 15 percent higher. Also, because most bakery products contain high amounts of sugar, it is usually highly palatable and can therefore be an excellent unconventional source of ingredient to poultry feeds. Bakery byproduct varies in nutrient profile depending on its source products. It, therefore, has the potential to be used primarily as an energy source in poultry feeds. Stale bread and other pastry products from stores or bakeries can be fed to poultry in limited amounts. These products are sometimes fed as received without drying.

The most common cereal grain substitutes used as energy supplements are grain sorghum, wheat and barley. Wheat bran is the most preferred and utilized unconventional energy supplement in poultry feed. Also, the rice bran due to its high oil (14-18%) and protein contents is a nutrient dense feed ingredient and hence the analysed gross energy density of rice bran in this study indicates that it has a good potential for being utilized as energy supplements in poultry feeds. The oil of rice bran is sometimes recovered by solvent extraction because of its high commercial value, especially in countries where demand for cooking oil exceeds supply. Also, the maize meal due to its relatively higher carbohydrate content has good potential for being utilized as energy supplement in poultry feeds, however, its low protein content appears to be a limitation and hence should be supplemented with some protein rich feedstuffs for its proper utilization by the poultry.

The nutritive richness in terms of gross energy density of the collected unconventional feed ingredients analyzed during this study indicates that these are nutritionally rich ingredients that could find their way in nutritionally-balanced, cost-effective formulated poultry feeds. Based on the results of the gross energy content of the collected feed ingredients, nearly 36 feed ingredients of animal and plant origin collected from markets in Farasan Island of Jazan region in KSA and in India, are the potential energy supplements for poultry feeds. The data generated during this study will be of use in preparing low-cost feeds for the culture of poultry farming.

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Table 1: Unconventional feed ingredients and the localities from where the feed ingredients were collected

Feed ingredients	*Sampling site*
Brans	
Wheat bran	Local Market, New Delhi
Flours	
Corn flour	Local Market, New Delhi
Wheat flour	Local Market, New Delhi
Husks	
Bengal gram husk	Local Market, New Delhi
Maize husk	Local Market, New Delhi
Lentil husk	Local Market, New Delhi
Bean covering	Local Market, New Delhi
Peels	
Banana peel	Local Market, Farasan
Mango peel	Local Market, Farasan
Mausmi peel	Local Market, Farasan
Potato peel	Local Market, Farasan
Orange peel	Local Market, Farasan
Watermelon Peel	Local Market, Farasan
Papaya peel	Local Market, Farasan
Bottle guard (Loki) Peel	Local Market, Farasan
Ridge guard (Turai) Peel	Local Market, Farasan
Seeds	
Blueberry seed	Local Market, Farasan
Weeds	
Mango leaves	Local Market, New Delhi
Water hyacinth (*Eichornia crassipes*)	Local pond, Near Mehrauli, New Delhi
Submerged weed (*Hydrilla verticillata*)	Local pond, Near Mehrauli, New Delhi
Algae	Local pond, Near Mehrauli, New Delhi
Roughage	
Sugarcane roughage	Sugarcane juice vendor, New Delhi
Beet root meal (Juice extracted)	Local Juice vendor, Farasan
Pineapple waste	Local Market, Farasan
Pumpkin waste	Local Market, Farasan
Abattoir waste	
Goat liver	Local Abattoir, J&K, India
Blood	Local Abattoir, J&K, India
Chicken Viscera	Local Market, Farasan
Earthworms	
Earthworm meal	Agricultural field, New Delhi
Grains	
Wheat middlings	Local Market, Jazan
Broken maize	Local Market, Jazan
Pearl millet (Bajra) *Pennisetum glaucum*	Local Market, Jazan
Sorghum	Local Market, Jazan
Semolina	Local Market, Jazan
Bakery wastes	Local Market, Jazan

Table 2: Gross energy densities of locally available, unconventional feed ingredients of animal origin (n=4)

Unconventional feed ingredients	*Gross energy density (kJg^{-1})*
Earthworm meal	16.39±0.01
Abattoir wastes	
Goat liver	23.73±0.03
Blood meal	19.86±0.02
Chicken viscera	17.01±0.05

Table 3: Gross energy densities of different locally available brans, hulls, broken grains and wheat middlings (n=4)

Feed ingredients	*Gross energy density ($kJ\ g^{-1}$)*
Brans	
Wheat bran	17.59±0.03
Rice bran	17.75±0.01
Flour	
Corn flour	16.93±0.03
Wheat flour	14.58±0.04
Maize flour	16.69±0.01
Husks	
Bengal gram husk	15.94±0.02
Maize husk	15.45±0.01
Bean covering	13.31±0.03
Peels	
Banana peel	13.76±0.02
Watermelon peel	16.11±0.01
Mango peel	14.21±0.04
Mausmi peel	12.81±0.02
Papaya peel	13.76±0.03
Potato peel	17.92±0.01
Bottle guard (Loki) peel	16.97±0.04
Ridge guard (Torai) peel	17.06±0.02
Seed	
Blueberry seeds	19.16±0.01
Leaves/Weeds	
Mango leaves	16.03±0.02
Algae	12.81±0.01
Water hyacinth (*Eichornia crassipes*)	15.16±0.04
Submerged weed (*Hydrilla*)	14.50±0.05
Grains	
Sorghum (Jowar) *Hordeum vulgare*	16.11±0.01
Wheat middlings (*Triticum*)	17.76±0.03
Bajra (Pearl millet) *Pennisetum glaucum*	16.97±0.01
Lentil husk	15.45±0.02
Semolina	15.74±0.01
Bakery waste	16.27±0.03
Underutilized by-products	
Papaya waste	13.76±0.02
Potato waste	17.92±0.01
Pumpkin waste	17.34±0.03
Lentil husk	15.12±0.01
Bakery by-products	17.02±0.02
Roughages	
Beet root meal (juice extracted)	13.72±0.01
Sugarcane roughage	13.64±0.03
Pineapple waste	14.54±0.01