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Original Research Article

Physicochemical and Functional Properties of Chicken By-products as a Source of Animal Feed

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Abstract: The purpose of this study was to determine the physicochemical and functional properties of chicken byproducts, including head, feet, intestine, and feather that may be potential sources of animal feed. Poultry waste is not typically processed into other useful products. There are issues such as the unpleasant odor of the waste, flies, and environmental risks that may disturb the community and residents living nearby. The samples of chicken byproducts were collected from a slaughterhouse and stored at a temperature of 3-4 ˚C before analysis. The findings revealed that the chicken head had the highest content of protein (87.36%) and ash (4.46%), whereas the intestine had the highest moisture content (83.69%), fat (1.45%), and crude fiber (0.2%). It was also found that the intestine had the highest water absorption capacity (6.03 ml/g), while the feather had the highest oil absorption capacity (8.36 ml/g). Overall, it can be deduced that chicken byproducts can potentially be utilized as a source of animal feed.

Keywords: Chicken wastes; physicochemical properties; functional; source; animal feed

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1. Introduction

There is a broad range of meat such as beef, lamb, duck, turkey, and chicken with rising demands. Generally, chicken is one of the most devoured meat types in most religions and cultures worldwide (Seong *et al.*, 2015). Chicken byproducts were derived from the clean

parts of the slaughtered chicken, including feet, intestine, neck, immature eggs, and feathers during chicken processing. Slaughtering is the first step of processing chicken meat for sale.

The slaughterhouse typically has a chicken processing capacity of approximately 20.000 to 30.000 chickens per day, which gives a total of roughly 10 million slaughtered chickens annually (Chicken & Parts, 2014). According to Industry Statistics (2017), broilers' weekly production in Peninsular Malaysia had increased from 414,350,008 in 2004 to 818,649,109 in 2017. Around 3.2 to 3.7 % of the waste's live weight was composed of blood (Jayathilakan *et al*., 2012).

The processing of chickens also resulted in the production of other wastes such as feather (live weight: 7 to 8%), intestine, proventriculus, and gizzard (live weight: 8.5–9.0%), head (live weight: 2.5–3.0%) and feet (live weight: 3.5–4.0%). Therefore, the amount of waste produced was approximately 28.2–31.9% (Jayathilakan *et al*., 2012). The issues in chicken processing are the unpleasant odor of the waste, flies, and environmental risks that may disturb the community and residents living nearby. Converting the wastes into other products is foreseen to be a feasible solution to the problems. Chicken wastes (Figure 1) have higher protein content than other animal wastes, which is advantageous for a source of ruminant feed (Kazemi-Bonchenari *et al*., 2017). Thus, this study has two aims to achieve. First, we want to determine the physicochemical properties like weight, moisture content, proximate analysis, and calorific value. Secondly, it is to determine the functional properties like water holding and oil absorption capacities of chicken byproducts, which can potentially be utilized as a source of animal feed.

2. Materials and Methods

Fresh chicken wastes such as head, feet, intestine, and feather were obtained from a chicken processing industry in Selangor. The wastes were transported to the laboratory at ambient temperature.

2.1. Preparation of Samples

The wastes were washed under running water to remove contaminants such as feces, dirt, and blood. The head and feet were minced and heated in a water bath at 85 ˚C for 20 minutes (Taheri *et al*., 2013). Distilled water (1:2 ratio) and Alcalase enzyme (Merck, Germany) were added into the substrate, and the mixture was placed into a shaking incubator for continuous agitation at 200 rpm at a temperature of 52.51 ˚C (Taheri *et al*., 2013). The

solution was heated at 95 ˚C for 20 minutes. After 20 minutes of centrifugation at 6700 x g, the supernatant was freeze-dried for four days, which formed protein hydrolysate powder, as shown in Figure 2. The intestine was dried for 24 hours at 105 ˚C using an oven (OF-G22W, Jeio Tech, Korea). The dried intestine (Figure 3) was ground into powder form. The powder of protein hydrolysate and intestine were kept in a chiller (TD-1600, PROTECH, Malaysia) at 3-5 ˚C. The feather was washed using hot water and dried in the oven at 105 ˚C. The dried feather (Figure 4) was ground and stored at room temperature.

Figure 1. The chickens

Figure 2. The protein hydrolysate powder

Figure 3. The dried intestine

Figure 4. The dried feather

2.2. Physicochemical Properties

2.2.1. Determination of weight

The fresh samples, including the head, feet, intestine, and feather, were weighed using a digital weighing balance with 0.0001 g of accuracy (ER-120A, AND, Japan).

2.2.2. Proximate composition

2.2.2.1. Moisture content

The crucibles were washed and dried in the oven at 100 ˚C for 30 minutes. They were allowed to be chilled inside the desiccator. Upon cooling down, a weighing balance was used to determine the initial weights of the crucible. The first weight after the crucibles were filled with fine ground samples (3.0 grams) was recorded. The samples were dried at 100 ˚C for 4 hours and then kept in the desiccator for cooling. They were then weighed repeatedly until constant weights for 30 minutes at a constant temperature were obtained to determine the filled crucible's final weight. The percentage of the sample's moisture content was estimated based on Helrich & Association of Official Analytical Chemists (1990) as equation below:

$$\textbf{Moisture content} = \frac{(\textbf{The initial weight of the filled crucible}) - (\textbf{Final weight of filled crucible})}{(\textbf{The initial weight of the filled crucible}) - (\textbf{Initial weight of empty crucible})} \times \mathbf{100} \quad (1)$$

2.2.2.2. Crude protein

The Kjeldahl method, which was based on Helrich & Association of Official Analytical Chemists (1990), was used to determine the samples' crude protein content, which involved digestion and distillation of protein. Approximately 1.0 g of the sample was weighed, and one tablet of Kjeldahl Catalyst was added to the protein digestion Kjeldahl flask. 12.5 ml of concentrated sulphuric acid was then poured into the Kjeldahl flask. The chemical handling should be done in the fume cabinet. Initially, the heating turns slow and prolonged with intermittent vibrations until the solution acquires a green color. The solution was digested for 2 hours at a temperature above 420 °C. After digesting, the solution was allowed to cool down, and the flask neck was cleaned with distilled water. After that, the solution was poured into a Kjeltec distillation apparatus (KjeltecTM 2300, Foss Analytical, Denmark) for the distillation process to determine the percentage of crude protein.

2.2.2.3. Fat

Soxtec Extraction (SoxtecTM 2050, Foss Analytical, Denmark) was used to determine the sample's total fat. First, a clean aluminum cup of 250 ml was dried for 30 minutes in an oven at 105 ˚C and then cooled in a desiccator. After that, the weight of the aluminium cup was recorded. 80 ml of petroleum ether with a boiling temperature of 40 ˚C to 60 ˚C was poured into the aluminum cup. Then, the thimbles were labeled and filled with

about 1 gram of each sample. After drying, it was cooled in a desiccator and weighed. The fat percentage was determined using the equation below (Helrich & Official Analytical Chemists' Association, 1990):

$$\text{Percentage of fat} = (\text{Weight of fat}) / (\text{weight of sample}) \times 100\% \quad (2)$$

2.2.2.4. Ash

The ash content was estimated using furnace incineration. It was based on water vaporization and volatiles with burning organic compounds in the presence of oxygen in the air to carbon dioxide at 550˚C. 1 gram of the finely-ground dried sample was filled into a porcelain crucible and incinerated for 6 hours at 525˚C in an ash muffle furnace (KSL-1700X, MTI Corporation, USA). The ash obtained was weighed after being cooled in a desiccator. The following equation was used to calculate the percentage of ash content in the samples (Helrich & Association of Official Analytical Chemists, 1990):

$$\text{Percentage of ash} = (\text{Weight of ash}) / (\text{weight of the original}) \times 100\% \quad (3)$$

2.2.2.5. Crude fiber

Horwitz & Association of Official Analytical Chemist (2000) method was used to determine the percentage of crude fiber. California Buchner was installed in the filtration apparatus (Model AS-2000, Analytical Bio-Chemistry Laboratories, Columbia) near the end of the reflux, equipped with a No. 9 rubber stopper to provide vacuum sealing, and the vacuum was balanced to approximately 25 mmHg or 735 mm pressure. After the filtration was performed using a 25 mm vacuum, the residue was washed with four near-boiling H_2O portions of 40-50 ml and filtered out. A near-boiling solution of 1.25% NaOH was used to wash off the residue from a funnel to a reflux beaker. The beakers were placed on the reflux apparatus for 30 minutes of reflux with 5 minutes intervals.

The liquid was decanted through the crucible at the end of refluxing, and the solids were washed with near-boiling H_2O. The residue was washed once by using 25-30 ml of a near-boiling 1.25% H_2SO_4 solution. The weight of residue before drying was recorded as W_1. The residue was dried at 130 ±2 ˚C for 2 hours or 110 ˚C overnight, and then cooled in a desiccator and weighed (W_2).

The ash was formed by burning the sample in the furnace at 550 ±10 ˚C overnight. Before being weighed, it was kept in a desiccator for cooling (W_3). The percentage of crude fiber can be calculated by using the equation below:

$$\text{Percentage of crude fiber} = [(W_2 - W_3) - (B_2 - B_3)] / W_1 \times 100 \quad (4)$$

B_2 and B_3 are average weights of all blanks after oven drying and ashing, respectively (Horwitz & Association of Official Analytical Chemist, 2000).

2.2.3. *Carbohydrate*

The percentage of a sample's carbohydrate content was obtained by subtracting the moisture, crude protein, fat, ash, and fiber content total values with 100.

2.2.4. *Calorific Value*

The samples were prepared, and the oxygen was charged as indicated in the operating instruction manual of Parr 1341 Oxygen Bomb Calorimeter. The water temperature was relatively 1.5 ˚C under room temperature. The weight of the sample was approximately ±0.5 grams. Each run was repeated three times.

2.3. Functional Properties

2.3.1. Water holding capacity

The water holding capacity (WHC) is defined as a sample's ability to retain its water content. The techniques proposed by Rodríguez-Ambriz *et al*. (2005) and Taheri *et al*. (2013) were employed in this study. 100 mg of sample were stirred in 1000 µl of distilled water by using a stirrer. The protein suspension was centrifuged for 20 minutes at 1800 ×g at a temperature of 220 °C. Then, the supernatant was discarded from the tube at an angle of 45˚ after 10 minutes. The initial volume of distilled water was added to the protein sample, and the supernatant volume was determined. Both volumes were used to calculate the difference (Kanu *et al*., 2009). The WHC is the amount of water absorbed (ml) per protein sample (g).

2.3.2. Oil absorption capacity

The oil absorption capacity (OAC) is defined as the ability of a sample to uptake oil. Based on Taheri (2013), Lin & Zayas (1987) technique was used due to its reliability and validity. The protein sample (100 mg) was mixed simultaneously with sunflower oil (1000

µl) using a vortex mixer for 30 seconds. The emulsion was incubated for 30 minutes at room temperature. Then, it was centrifuged for 10 minutes at 13600 ×g. The supernatant was discarded for 20 minutes at an angle of 45˚. The amount of oil absorbed and the fat absorption of the sample was equal. The volume of the hydrolysate oil segregation was measured, and oil absorbed (ml) by protein sample (g) was recorded as the OAC (Kanu *et al*., 2009).

2.4. Statistical Analysis

The collected data were analyzed using Minitab Statistic 16 Edition with a one-way Variance Analysis (ANOVA). It was carried out to evaluate the substantial differences between mean values with a confidence level of 95% ($P < 0.05$) for the results as a function of chicken byproduct types. Tukey tests were performed to predict the homogeneous groups for the values of chicken byproducts' physicochemical and functional properties. All analyses were triplicated, and the mean of three independent experiments was interpreted as the results.

3. Results

3.1. Physicochemical Properties

3.1.1. Weight

Table 1 shows the weight and weight of each chicken waste, such as head, feet, intestine, and feather. The head, feet, intestine, and feather had mean weights of 45.27 ±2.75 g, 65.17 ±1.46 g, 151.67 ±2.08 g, and 95.87 ±1.20 g, respectively. The mean weight of the intestine was the highest, whereas the head was the lowest. The intestine had the highest live weight, which was 8.44%, followed by the feather, head, and feet, with 5.33%, 3.61%, and 2.5% of live weight.

Table 1. Weight for each chicken byproducts per one whole chicken on a wet basis

Chicken byproducts	Weight (g)	% of live weight
Head	45.27 ±2.75	2.5
Feet	65.17 ±1.46	3.61
Intestine	151.67 ±2.08	8.44
Feather	95.87 ±1.20	5.33

3.1.2. Proximate composition

Generally, foods such as flavor, weight, texture, shelf life, and appearance were influenced by the moisture content. The chicken byproducts' moisture content values were significantly different ($P < 0.05$), which ranges from 4.78% to 83.69%. The intestine and

feather's head and feet had mean moisture content values of 4.78 ±0.12%, 83.69 ±0.36%, and 13.10 ±0.20%. The intestine's moisture content was higher than those of Seong *et al*. (2015), who found that the intestine's moisture content was 82.61 ±0.90%. The head and feet showed the lowest moisture content values compared to the others. It is well known that the intestine consists of the small and large intestine that absorb water and nutrients (Organic Chicken Feed, 2011).

Table 2. The results of proximate compositions of chicken by-products

Properties	Head and feet	Intestine	Feather
Moisture content (%)	4.78 ±0.12^{c}	83.69 ±0.36^{a}	13.10 ±0.20^{b}
Crude protein (%)	87.36 ±0.39^{a}	12.59 ±0.32^{c}	82.43 ±0.32^{b}
Fat (%)	0.81 ±0.08^{b}	1.45 ±0.19^{a}	0.08 ±0.02^{c}
Ash (%)	4.46 ±0.28^{a}	1.38 ±0.22^{b}	0.90 ±0.16^{c}
Crude fiber (%)	0.00 ±0.01^{b}	0.20 ±0.03^{a}	0.00 ±0.00^{b}
Carbohydrate (%0	2.59 ±0.06^{b}	0.69 ±0.43^{c}	3.49 ±0.04^{a}
Calorific value (Cal / g)	5723.30 ±22.80^{b}	6826.90 ±63.70^{a}	0.00 ±0.00^{c}

Different letters indicate statistically significant differences exist $P < 0.05$ for each row. Means do not share a letter is significantly different. Tukey test was applied with 95% simultaneous confidence intervals.

Table 2 presents the percentage of crude protein of chicken byproducts. The crude protein found in the head and feet, intestine, and feather were 87.36 ±0.39%, 12.59 ±0.32%, and 82.43 ±0.32%, respectively. The head and feet mixture and feather had significantly higher crude protein values ($P < 0.05$). It indicates that both of these wastes are rich in protein and suitable for animal feed. The intestine had the lowest percentage of crude protein. It was also found that the crude protein of head and feet was higher than those of Taheri *et al*. (2012), who found that the head and feet protein content was 84.66 ±0.09%.

Productive performance in animals, including poultry, can be improved by fat supplement (Puteri Nurain, 2018). Based on Table 2, the chicken wastes' fat content was found significantly different ($P < 0.05$). The fat content in the head and feet mixture, intestine, and feather were 0.81 ±0.08%, 1.45 ±0.19%, and 0.08 ±0.20%, respectively. The chicken intestine was found to have the highest fat content. However, it was lower than the previous work by Seng *et al*. (2015), which was reported to be 1.82 ±0.07%. Meanwhile, the feather had the lowest percentage of fat content. For a better feed conversion rate and higher growth, fat should be regarded just as vital as proteins and carbohydrates (Çetingül, İ. S., & Yardimci, M., 2008). Thus, the intestine would potentially be a good source of energy.

As indicated in Table 2, the ash content found in the head and feet, intestine, and feather were 4.46 ±0.28%, 1.38 ±0.22%, and 0.90 ±0.16%, respectively. The highest percentage of fat content was head and feet, but it was lower than the previous work of Taheri *et al*. (2012), which was reported to be 4.70 ±0.34%. The feather had the lowest percentage of ash content. Ash residue is defined as the composition of minerals, often from animal sources like bone and meat. It is beneficial because the minerals are an essential part of an animal's diet (Puteri Nurain, 2018).

The crude fiber was unidentified in the head and feet mixture and feather of the chicken. The percentage of the crude fiber content in the intestine was 0.20 ±0.03%. Therefore, the intestine had a significantly higher percentage of crude fiber content ($P < 0.05$) than other byproducts. However, the intestine's crude fiber was less than 1%, which is considered negligible. The crude fiber content is essential as it relates to digestibility (Puteri Nurain, 2018). Crude fiber-rich feeds are less digestible than fiber-low feeds.

3.1.3. Carbohydrate

Carbohydrate is defined as organic compounds composed of sugar, starch, and cellulose. It is a primary source of animal energy. The animal energy required for energy metabolism comes from carbohydrate in the diets (Puteri Nurain, 2018). Table 2 shows the results of the mean carbohydrate. The carbohydrate content of head and feet, intestine and feather, were 2.59 ±0.06%, 0.69 ±0.43%, and 3.49 ±0.04%, respectively. Feather had the highest carbohydrate content ($P < 0.05$) compared to the others. In the meantime, the intestine had the lowest carbohydrate content.

3.1.4. Calorific value

The calorific value is a crucial property for animal feed or dietary products. It is defined as the total energy or calorie content in a sample. The calorific values of head and feet, intestine, and feather were determined, and the results are presented in Table 2. The mean calorific value for chicken head and feet mixture and intestine was 5723.32 ±22.80 Cal/g and 6826.87 ±63.70 Cal/g. Overall, the chicken intestine's total calorific value was the highest compared to the head, feet, and feather. The energy content is used frequently for differentiating diets and estimating the value (Van Saun & Herdt, 2014).

3.2. Functional Properties

Functional properties determine the behavior of materials during preparation and how they influence finished food products in terms of how it performs, looks and tastes. Functional properties include water holding capacity (WHC) and oil absorption capacity (OAC). The results of WHC and OAC for chicken wastes are presented in Table 3.

Table 3. Results of functional properties of chicken by-products

	Head & Feet	**Intestine**	**Feather**
Water Holding Capacity, WHC (ml / g)	2.00 ±0.18^{c}	6.03 ±0.17^{a}	3.12 ±0.20^{b}
Oil Absorption Capacity, OAC (ml / g)	2.03 ±0.17^{c}	5.75 ±0.12^{b}	8.36 ±0.11^{a}

Different letters indicate statistically significant differences exist $P < 0.001$ for each row. Means do not share a letter is significantly different. Tukey test was applied with 95% simultaneous confidence intervals.

3.2.1. Water holding capacity

Water holding capacity (WHC) is the result of the total pore space (percent V/V) and the suction force (either 1 cm water pressure or kPa) applied. As illustrated in Table 3, the WHC values of head and feet, intestine, and feather were 2.00 ±0.18 ml/g, 6.03 ±0.17 ml/g, and 3.12 ±0.20 ml/g, respectively. The highest WHC value was the intestine, whereas the lowest was the head and feet mixture. The intestine has more hydrophilic polar side chains that allow more water to be retained than the feather, head, and feet.

Furthermore, the amount of water absorbed has a significant impact on enzymatic hydrolysis, leading to polar group inflation concentrations, including COOH and NH2 (Taheri *et al*., 2013). Food with intermediate moisture (IM) can bind water and enhance texture through hydrolysate supplementation (Taheri *et al*., 2013).

3.2.2. Oil absorption capacity

Oil absorption capacity (OAC) is known as binding fat to the non-polar side chain of protein (Acuña, González & Torres, 2012). The result of OAC for the chicken wastes are shown in Table 3. The values of OAC for head and feet mixture, intestine, and feather were 2.03 ±0.17 ml/g, 5.75 ±0.12 ml/g and 8.36 ±0.11 ml/g, respectively. The feather had the highest OAC value, whereas the head and feet had the lowest OAC value. According to Taheri *et al*. (2013), the OAC is influenced by the hydroxyproline content. Powdered samples

can consume more fat as they contain large amounts of charged amino acids such as aspartic acid, glutamic acid, lysine, and arginine.

4. Conclusion

Based on the findings, the highest percentage of protein and ash content was the combination of chicken head and feet with the values of 87.36% and 4.46%. The intestine had the highest moisture content (83.69%), fat (1.45%), crude fiber (0.2%), and water holding capacity (6.03 ml/g) compared to other chicken wastes. Meanwhile, the feather had an oil absorption capacity of 8.36 ml/g, which is the highest value. In summary, the current findings show that there is potential for the head, feet, intestine, and feather to be sources or additional ingredients to existing animal feed. Therefore, the pollution caused by the wastes can be reduced as the wastes are utilized for beneficial purposes.

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