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Effect of drying temperature and time on chemical characteristics of duck bone meal

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ABSTRACT

Duck bone waste is still become community attention, especially in the Sidrap district, South of Sulawesi Province, because it has many ducks Palekko' food stalls that produce solid waste in the form of duck bone. Processing this waste into the innovative product (done bone meal) was essential to minimize the waste. This study aimed to determine the effect of drying temperature and time on the chemical characteristics of the duck bone meal. The processing method is a modification of previous research including washing, cutting, boiling bones, cleaning, drying, and flouring. The experimental design was a completely randomized experimental design (CRD), one factorial, consisting of 3 treatments and three replications, namely P1 (T_1 = 100^{O}C; t_1 = 5 hours), P2 (T_2 = 150^{O}C; t_2 = 3 hours), and P3 (T_3 = 200^{O}C; t_3 = 1 hour). Data were processed and tested ANOVA to see differences among treatments. If there was a significant difference among treatments at $\alpha \leq 5\%$, a further test was carried out using the least significant difference (LSD). The product was characterized by proximate composition, calcium content, and phosphorus content. The analysis was also carried out to compare the bone meal quality with standard (SNI 01-3158-1992). The duck bone meal that has the best characteristics was in the treatment of 200^{O}C and 1 hour drying time (P3) with an average result of 2.88% moisture content, 40.46% ash content, 0.47% fiber content, 40.71% protein, 13.81% fat content, 1.90% calcium content, and 8.56% phosphorus content.

ABSTRAK

Limbah tulang itik menjadi menjadi perhatian masyarakat khususnya masyarakat Kabupaten Sidrap, Sulawesi Selatan karena di wilayah ini terdapat banyak warung makan Palekko' itik yang menghasilkan limbah padat yaitu tulang itik. Langkah untuk meminimalisir limbah tulang itik ini adalah dengan mengolahnya menjadi produk inovasi yakni tepung tulang itik. Tujuan penelitian ini adalah untuk mengetahui pengaruh suhu dan waktu pengeringan terhadap karakteristik kimia tepung tulang itik. Metode pengolahan merupakan modifikasi dari penelitian sebelumnya meliputi diantaranya pencucian, pemotogan, perebusan tulang, pembersihan, pengeringan dan penepungan. Rancangan percobaan menggunakan rancangan acak lengkap (RAL) satu faktor dengan 3 perlakuan dan 3 ulangan yaitu P1 (T_1 = 100^{O}C; t_1 = 5 jam), P2 (T_2 = 150^{O}C; t_2 = 3 jam) dan P3 (T_3 = 200^{O}C; t_3 = 1 jam). Data diproses dan diuji ANOVA untuk melihat perbedaan diantara perlakuan. Uji lanjut dilakukan dengan beda nyata terkecil (BNT) jika terdapat perbedaan signifikan pada $\alpha \leq 5\%$. Karakteristik kimia produk dianalisis dengan komposisi proksimat, kadar kalsium dan kadar fosfor. Selain itu dilakukan perbandingan produk dengan standar mutu tepung tulang (SNI 01-3158-1992). Karakteristik kimia tepung tulang itik terbaik dihasilkan pada perlakuan suhu pengeringan 200^{O}C dan lama pengeringan 1 jam (P3) dengan rata-rata kadar air 2.88%, kadar abu 40.46%, kadar serat 0.47%, kadar protein 40.71%, kadar lemak 13.81%, kadar kalsium 1.90%, dan kadar fosfor 8.56%.

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1. Introduction

Indonesia has a biodiversity of poultry animals that have the potential for industrial development in the livestock sector. One of them is the duck which has advantages and has high economic value. According to [1], ducks have a high protein and fat content ranging from 8.26% - 20.04%, and 3.84% - 59.32%, respectively. Moreover, duck bone waste also has high economic value. So that, waste processing to be a valuable product will be very profitable as we know that bones contain much inorganic material, including calcium and phosphorus. In general, the bones composition consists of 60% inorganic material, 30% organic, and 10% water. Besides, several other minerals are also present in small amounts, including bicarbonate (HCO_3^-), magnesium (Mg), sodium (Na), potassium (K), copper (Cu), zinc (Zn), manganese (Mn), and others [2].

Duck bone was found in the Sidrap area, South of Sulawesi, as solid waste from Palekko's food stalls. These wastes may pose a potential hazard to human health or the environment (soil, air, water). Therefore, managing the duck bone is very important and be a community concern. Furthermore, these wastes may have processed into product innovation that has high value. Duck bone contains a mineral that was beneficial to human growth, such as calcium and phosphorus. Calcium and phosphorus content is needed as a substitute for food consumption with a balanced daily diet and supplemented with vitamin D [3]. So, one way to minimize duck bone waste so as not to pollute the environment is by processing duck bone into innovative products, namely, duck bone meal.

Nowadays, a high source of calcium is found in milk. However, because the milk price is high, we are looking for an alternative source of calcium that is cheaper, easy to obtain, and can be absorbed naturally by the body [4]. Duck bone meal obtained from duck bone waste will be the best alternative to be developed because it has high calcium, and phosphorus content. Besides, duck bone meal can also be used as a substitute for raw material for feed. Meat and bone meal contains about 45 - 55% protein [5]. According to [6], as much as 50% of the feed that is substituted with bone meal and meat can increase catfish (Pangasius sp.) seeds. Bone meal can also be used as a fortification in various product formulations widely recognized by the public. The example can be seen from the research of [7], namely making biscuits with Jangilus fishbone meal.

Many benefits of the bone meal have been stated above so that duck bone meal can be a potential product with high economic value and can be developed optimally. However, animal-based flour/meal/powder production, especially from duck bone, is still rare in Indonesia. This research tried to produce duck bone meal from waste Palleko's food stall that had the best characteristics and quality. Bone meal quality was affected by raw materials, processing, and condition process [8]. Several studies of bone meal processing had been done for fish bone meal, chicken bone meal, and meat bone meal [8-11]. However, the study on duck bone meal processing has not been carried out. The author sees that the study of duck bone processing is essential to reduce environmental pollution in the Sidrap area and increase the added value of duck bone waste.

Processing by softening duck bones can be efficient for the body. Softening and cooking will help to chew, contributing to increasing Ca intake from food [12]. However, we see that drying was necessary for the processing of duck bone meal. The drying stage was critical and influenced the quality of the bone meal. According to [13], time, drying temperature, and surface area can affect the product's water content. The drying method affected the moisture content and physicochemical, sensory, and nutritional properties of food [14]. The bone meal would have a small amount of moisture content when the drying process was performed flawlessly [11]. Besides, the drying processes have an impact on the yield of bone meal [15]. Bone meal composition and protein quality were also affected by condition processes such as pressure and temperature [8]. Increased pressure and temperature decreased the protein quality of bone meals [8]. According to [16], the nutritive value of meat and bone meals was affected by cooking times and temperatures. This support by [17] said the essential factors in bone meal processing are temperature and time. Drying temperature and time affect moisture content, yield, and ash content of bone meal [17]. Drying temperature and time also significantly affected the color of duck bone meal [18]. This research tried to produce duck bone meal from waste Palleko's food stalls with the best characteristics and quality. This research was aimed to determine the effect of drying temperature and time on the chemical characteristics of the duck bone meal.

Waste of poultry bones in Indonesia is abundant and still not fully utilized. With a certain concentration and quantity, waste has an unfavorable impact on the environment, such as global warming, water depletion, and indirect land-use change [19-20]. Bone is classified as solid waste from animal-based processing. Bone waste was usually crushed and made into a mixture of animal feed [21]. In order to increase the utilization of waste, many studies have been developed to produce various products from bone waste, including animal feed, gelatin, meal, powder, flour, or calcium phosphate [10, 22-24]. Bone meal is a co-product of the food industry that uses animals as raw materials. Bone meal has great potential as a processed food raw material because the bone meal has high mineral content. One of the most abundant minerals in bones is calcium and phosphorus [10-11, 24-25]. Calcium is a mineral essential that plays a role in nerve conduction, muscle contraction, and blood flow. According to [26-27] in the [4], calcium is needed for the process of forming and maintaining skeletal body tissue as well as several important activities in the body such as helping in regulating the ions transport, playing a role in the reception and interpretation of nerve impulses, blood clotting, and blood pumping, muscle contraction, maintaining hormonal balance and catalysts in biological reactions. Adults need 800 mg of calcium/day [28]. Calcium deficiency causes bone growth disorders, osteoporosis, and osteomalacia [28].

Bone meal also has a small amount of amino acid [29]. As an animal feed, a tiny amount of protein in the bone meal can be helpful for fish growth. According to [30], fish generally need food with protein content ranging from 20-60%, while optimum levels range from 30-36%. In general, fish need more significant protein than land-based livestock. Besides, the type and age of fish also affect the amount of protein required for young carnivorous fish that require more protein than adult fish. Besides being used as feed, bone meal can also be used as a substitute for making biscuits. Meal dramatically affects the texture of the baked product, the hardness, and the shape of the biscuits. These effects are different for different kinds of biscuits and relate to the fat and sugar enrichment and the dough mixing technique. If the ash content of the meal was too high, the function of gluten during baking was disturbed, and the structure of the biscuits would be different [31].

Bone meal's composition and protein quality are affected by the raw materials used, processes used, and the processing conditions employed [8]. The bone meal had been processed from fish, cattle, and chicken as raw materials. Several studies on bone meal processing and their quality were done, such as tilapia fish bone meal was known to contain up to 40.8% protein content [32], the protein content of tuna fish bone meal reaches 29 - 56% [33], while catfish head meal reaches 9.9 - 11.4% protein content [34]. According to [35] stated that the nutrient content determines the quality of a feed because the fish will use the feed to obtain energy according to their needs efficiently. The addition of fishbone powder increased the calcium content, ash content, phosphorus content, and whiteness level of the food product [36]. According to [37], adding 5% of chicken bone to the cookies will increase the fat content, protein content, ash content, and calcium content. The physicochemical characteristics of chicken bone flour was 34.63% yield, 4.92% moisture content, 46.89% protein, 13.79% fat, 31.50% ash, 2.90% carbohydrate content, density 0.60 g/ml, water absorption 138.57%, degree of whiteness 49.47%, and calcium content 18061.12 mg/100 g [37]. Besides, the consumption of ratio calcium and phosphor is necessary for the absorption process. The ratio for proper

absorption requires a ratio of calcium to phosphorus in the intestinal cavity of 1:1 to 1:3. Ratio calcium and phosphorus greater than 1:3 will inhibit calcium absorption [17].

Moisture content in the duck bone meal is significant. Water affects appearance, texture, and taste [24]. The higher the water content, the faster the damage will occur to the meal. Low moisture content also allows the bone meal to resist microbial deterioration because moisture content at 2% is not sufficient for microbial growth [37]. Based on this, it is necessary to do proper drying. According to [38], the higher the drying temperature, the faster evaporation occurs, so that the water content in the material decreases.

Meanwhile, according to [39], the higher the drying temperature and the longer the time was used to dry material, the more water evaporates. Different drying method of bone powder affects the nutritional composition, antioxidant property, physical property, energy consumption, and flavor [9]. Different drying methods treatment such as spray drying, hot air drying, freeze-drying, and infrared freeze-drying on a chicken meal resulting from infrared freeze-drying, was the best method in chicken bone processing [9]. Researchers [37] compare two different drying methods that were oven drying and cabinet dryer. According to [37], a cabinet dryer was the best method to produce a bone meal with a higher yield, moisture content, protein content, fat content, and ash content.

2. Research Methodology

2.1. Materials

Materials used in this research were duck bone waste (samples) that were obtained from one of the food stalls Palekko 'duck in Sidrap and chemical materials such as aquades, catalyst mixture of selenium, HCl, NaOH, boric acid, indicator bromocresol green, indicator methyl red, hexane, HNO_3, metil petaline, phosphate 1 and 2. In addition, equipment to prepare the duck bone meal. Other equipment to analyze product was glassware, oven, aluminum cup, desiccator, scale, furnace, hot plate, analytical balance, Kjeldahl distillation apparatus, magnetic stirrer, conical flask, soxhlet, filter paper, boiling flask, aluminum foil, basin, grinder, knives, spectrometer, and press cooker.

2.2. Experimental Design

The research began with taking a sample of duck bone waste from Palekko stalls. The duck bone process used modification of [40] methods. This research was conducted using a completely randomized design (CRD), one factorial, drying temperature, and time. There were three treatments namely P1 (T_1 = 100^OC and t_1 = 5 hours), P2 (T_2 = 150^OC and t_2 = 3 hours) and P3 (T_3 = 200^OC and t_3 = 1 hour) with three replications of each treatment. As for P1 is the first treatment, P2 is the second treatment and P3 is the third treatment, T is drying temperature, and t is drying time. The best result was compared to the standard of bone meal quality (SNI 01-3158-1992) [41].

2.3. Processing of Duck Bone Meal

The duck bone was cleaned and cut to 3cm. First, the bones are boiled at 100^0C for 15 minutes. Furthermore, the bones were immersed in 0.8% HCl for 6 hours and then cleaned five times. Furthermore, the bones were steamed using a press cooker for 2 hours, dried with three treatments, and ground.

2.4. Characterization of Product

The product that was characterized was duck bone meal. The products were characterized by parameters of moisture content using the oven method, protein content, fat content using Soxhlet, crude fiber, and ash content [42]. Besides, the product was analyzed by calcium content [43] and phosphorus content [44]. Product characterization was done in the Animal Nutrition Laboratory, Faculty of Animal Husbandry, University of Hasanuddin.

2.5. Data Analysis

The data analysis technique used is a quantitative and analytical analysis using the ANOVA using the SPSS application to determine the effect of drying temperature and time on the chemical characteristics of the duck bone meal. A further test was carried out using the least significant difference (LSD) if there was a significant difference in treatments at $\alpha \leq 5\%$.

3. Result and Discussion

3.1. Moisture Content

Result of analysis of variances on moisture content of duck bone meal showed that P1 (T_1 = 100^OC and t_1 = 5 hours) had a significant difference with P2 (T_2 = 150^OC and t_2 = 3 hours) and P3 (T_3 = 200^OC and t_3 = 1 hours) on the resulting moisture content ($p < 0.05$). The lowest water content of 2.88% was obtained from P3 (T_3 = 200^OC and t_3 = 1 hour). The result showed that increasing temperature leads to a decrease in moisture content in the duck bone meal. According to [11], all water molecules can be released when drying was carried out. The water molecules found in bones are not included in the bone tissue but are attached to the bone surface. Low moisture content makes the bone meal more stable at room temperature and inhibits bacterial growth so that the shelf life of the meal was longer. In addition, the low moisture content will make the meal easier to use as additive materials in various applied products. The moisture content of duck bone meal ranged from 2.88% to 4.85 (Table 1). This result is still below the standard set by SNI 01-3158-1992. Based on [41], the bone meal has a maximum moisture content of 8%. Meanwhile, according to [45], the good moisture content for the bone meal is 6.6%.

Table 1. Average chemical characteristics of duck bone meal in various treatments.

Treatment (Drying temperature and time)	Moisture content (%)	Ash content (%)	Protein content (%)	Fat content (%)	Fiber content (%)	Calcium content (%)	Phosphorus content (%)
P1 (T_1 = 100 ^{O}C and t_1 = 5 hours)	4.85^b	36.82^b	40.87^a	19.63^b	0.10^a	1.73^a	7.63^b
P2 (T_2 = 150 ^{O}C and t_2 = 3 hours)	3.26^a	40.56^a	40.94^a	15.05^a	0.33^a	1.78^a	8.21^a
P3 (T_3 = 200 ^{O}C and t_3= 1 hours)	2.88^a	40.46^a	40.71^a	13.81^a	0.47^a	1.90^a	8.56^a

Note: The numbers followed by the same letter in the same column are not significantly different based on the 5% LSD test.

3.2. Ash Content

The results of the analysis of variance showed that P1 (T_1 = 100^{O}C and t_1 = 5 hours) had a significant difference with P2 (T_2 = 150^{O}C and t_2 = 3 hours) and P3 (T_3 = 200^{O}C and t_3 = 1 hours) on the ash content ($p < 0.05$). The ash content of duck bone meal ranged from 36.82% to 40.56% (Table 1). This result showed that all minerals (including calcium, magnesium, phosphate, and carbonate) are contained within the material and undergo an ashing process. The highest ash content was produced at P2 (T3 = 150 OC and t3 = 3 hours), indicates that the drying temperature and time affected the ash content of the duck bone meal. Decreasing temperature and increasing drying time lead to decreasing ash content of the bone meal. However, if the temperature is too high, it will reduce the ash content produced. Compared to the fishbone meal produced by [46], the ash content was only around 33.0%. It proved that the ash content of duck bone meal was still higher.

Ash content affects immersion in alkaline solutions to release organic matter, especially protein. A comparison of ash content and protein content is an important criterion to show bone mineralization related to the level of bone hardness [25]. However, in this study, the alkaline solution was not immersed in obtaining high protein yields. This result can be a choice in making duck bone flour itself, whether the protein content to be maintained or the percentage of minerals to be maintained. It just depends on the usage.

3.3. Protein Content

The analysis of variance on protein content showed that the drying temperature and time had no significant difference ($p > 0.05$). The protein content of duck bone meal ranges from 40.71% to 40.94%, which can be seen in Table 1. The protein content of duck bone meal was relatively high because releasing organic matter with an alkaline solution is not carried out. According to [25], variations in the protein composition of each bone meal are affected by variances in the preparation process. Using an alkaline solution will be more effective in hydrolyzing the protein in bones. However, it cannot be used as a basis for the effectiveness of overall protein removal because some protein is still left in the bone meal. A high percentage of protein content can be an option in using duck bone meal to make products with high protein. In addition, according to [47], the drier the material, the higher the protein content. The decrease in water content will increase the protein content of the material. The use of heat in food processing can reduce the water content and increase protein content.

3.4. Fat Content

The result of analysis of variance carried out on fat content showed that P1 (T_1 = 100^{O}C and t_1 = 5 hours) had a significant difference with P2 (T_2 = 150^{O}C and t_2 = 3 hours) and P3 (T_3 = 200^{O}C and t_3 = 1 hours) on the resulting fat content ($p < 0.05$). The fat content of duck bone meal ranges from 13.81% to 19.63% (Table 1). Increasing the temperature and decreasing the drying time leads to decreasing the fat content of the duck bone meal produced. In line with the research of [48], an increase in fat content with high drying temperatures could be caused by a decrease in moisture content so that the percentage of fat content increased. Meanwhile, high-fat content occurs due to the destruction of fat due to the relatively high drying temperature. Fat is a compound formed as a result of the esterification reaction between glycerol and fatty acids. The heating application to the fat will break the double bonds in the fat so that the fat will be decomposed into glycerol and fatty acids. The fat content of the duck bone meal showed a high enough and was above the standard set by SNI. Based on [41], the bone meal has a maximum fat content of 6%. The high-fat content will affect the aroma and flavor of the bone meal and will easily cause lipid oxidation [26]. Treatment needs to be done to reduce the fat content of the bone meal produced, for example, soaking it with an alkaline solution even though it is known that fat has complex bonds that are difficult to remove [11].

3.5. Fiber Content

Based on the analysis of variance, the treatment of drying temperature and time had no significant difference ($P < 0.05$) influence the fiber content of duck bone meal. The fiber content of duck bone meal ranged from 0.10% to 0.47%, as shown in Table 1. The result showed that the fiber content increases with increasing temperature and decreasing of the drying time. Decreasing the fiber content causes better nutrient absorption. Crude fiber is related to the rate of digestion and absorption of nutrients. When the fiber content of a food product is higher, the rate of digestion and absorption of nutrients becomes slower [49].

3.6. Calcium Content

The analysis of variance showed that the drying temperature and time had no significant difference in the calcium levels ($p > 0.05$). The calcium content of the duck bone meal ranged from 1.73% to 1.90%, which can be seen in Table 1. The calcium content of the duck bone meal showed that the calcium level is relatively low and is below the standard set by SNI. Based on [41], the bone meal has a maximum calcium content of 20 - 30%. This is because the alkaline solution (NaOH) is not immersed in duck bone meal production, which can allow the amount of calcium to settle in the bone matrices [25].

3.7. Phosphorus Content

The results of the analysis of variance showed that P1 (T_1 = 100^{O}C and t_1 = 5 hours) had a significant difference with P2 (T_2 = 150^{O}C and t_2 = 3 hours) and P3 (T_3 = 200^{O}C and t_3 = 1 hours) on the levels of phosphorus ($p < 0.05$). The phosphorus content of duck bone meal ranged from 7.63% to 8.56%. It can be seen in Table 1 that the phosphorus content produced in this study is still relatively high compared to the results of the study of belida fish bone meal [25] which is in the range of 3.98% to 4.06%. According to [50], the method used in making bone meals will produce different characteristics of bone meals. The use of different temperatures, times, and methods will produce different levels of phosphorus. According to [26], calcium and phosphorus found in bones will form calcium-phosphate in an alkaline atmosphere. Calcium-phosphate is a mineral crystal that is insoluble at alkaline pH.

4. Conclusion

The preparation of duck bone meal which produces the best characteristics, was in the treatment of drying temperature of 200^{O}C and drying time of 1 hour (P3) with an average moisture content of 2.88%, an ash content of 40.46%, the fiber content of 0.47%, the protein content of 40.71%, the fat content was 13.81%, the calcium level of 1.90% and the phosphorus content of 8.56%.

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