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Evaluation of Physical and Chemical Properties of Cassamore Containing Palm Kernel Meal Processed by Steam as Corn Substitute Feed

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Abstract Cassamore is a feed ingredient containing cassava, palm kernel meal and moringa, made as a substitute for corn feed. This study aimed to evaluate steam's effect on the physical, chemical and total solubility properties of cassamore. This study used a completely randomized design (CRD) with 4 treatments and 4 replications. The treatments applied were ground corn (P0), cassamore without steam (P1), cassamore steam for 5 minutes (P2) and cassamore steam for 10 minutes (P3). Data on physical properties and total solubility were analyzed using ANOVA and, if significantly different ($P<0.05$), continued with Duncan's test, while chemical properties were analyzed descriptively. Based on the research results, the physical properties of cassamore were different compared to corn. Steam treatment increased the bulk density, tapped density and angle of repose in the cassamore significantly ($p<0.05$). Meanwhile the duration of steam has no significant effects on physical properties parameters. Total solubility between corn and cassamore was the same and could not be increased by steam treatments and the difference is not significant ($p>0.05$). Based on descriptive analysis, both steamed and non-steamed cassmore had nutritional equivalents to corn but had higher crude fiber and slightly lower energy so that cassmore has potential value to substitute corn.

Keywords Steaming Process, Cassava, Physical and Chemical Properties, Feedstuff

1. Introduction

Corn is a major feed ingredient used for poultry feed because it has good nutritional value and palatability. The proportion of corn used in chicken feed generally ranges from 45%–55% [1]. The increase in the corn price causes the chicken feed to increase. Feed contributes 60%-80% of the production cost of chicken farming [2]. Therefore, studies are needed for alternative energy source feed as a corn substitute.

Cassamore is a feed ingredient made from cassava and moringa as an alternative energy source to substitute corn. However, the combination of cassava and moringa produced feed ingredients with a lower protein content than corn. Therefore, it is necessary to add palm kernel meal to increase the protein content so that it has a nutrient equivalent to corn.

Previous research showed that cassava flour can replace corn by up to 50% and performs similarly to broiler chickens fed corn-based feed [3-4]. The starch consists of amylose and amylopectin. Cassava had an amylopectin content of 65.26%, while corn had 57.41% of the total starch [5]. The higher amylopectin content in cassava made cassava starch more difficult to digest. Compared to amylose, the amylopectin molecule has α 1,6-glycosidic branch bond. Amylopectin is less soluble in water and more difficult to digest for poultry [4]. In addition, cassava leaves can also be used as feed ingredients. Using cassava leaves is expected to increase the protein contained in cassava.

The antinutritional components of cassava include cyanogenic glycosides (2.06±0.008mg/L), trypsin inhibitor (4.28±0.03TUI/mg), phytate (31.02±0.34mg/100g), tannins (3.64±0.009mg/100g), oxalate (1.29±0.029g/100g) [5]

Moringa oleifera leaves can be used as a feed supplement in animal feed. That can increase the nutritional value of chicken feed. Moringa leaves are a source of provitamin A, vitamin B, vitamin C, iron, and β -carotene. Moringa leaves can be used as a source of β-carotene, which is not found in cassava and other cassava ingredients. In addition, Moringa leaves contain macro minerals, including potassium, calcium, magnesium, sodium, phosphorus, and microminerals, including manganese, zinc, and iron [6]. It is hoped that adding moringa extract can produce feed ingredients with better performance than corn.

Palm kernel meal is one of the animal feed ingredients derived from palm oil processing industrial waste. Palm kernel meal contains a fairly high protein content, ranging from 14–17%. However, palm kernel meal had contaminants in the form of palm shells, which are high in fiber and have low digestibility [7].

The use of steam in the cassamore production process needs to increase the digestibility of the cassamore. Hydrothermal treatment, such as steam, can increase starch digestibility in broiler feed [8]. In the process of making feed, steam in the tool is called conditioning, which belongs to the hydrothermal process. Steaming can also reduce the anti-nutritional content contained in feed ingredients.

Cassamore as a substitute for corn, its physical and chemical properties must be known to determine the proper handling, use and storage. Although total solubility cannot describe the utility or digestibility of Cassamore. However, it can be measured as a physical property. Until now, there has yet to be any information about the physical properties, chemical properties and total solubility of cassamore. This study aimed to evaluate the effect of adding steam on the physical properties, chemical properties and total solubility of cassamore containing palm kernel meal as a substitute for corn.

2. Methods

2.1. Time and Location

This study was conducted from September 2022 to February 2023. The production process and analysis of physical properties are carried out at the Feed Industry Laboratory, Faculty of Animal Science, IPB University. Proximate analysis was carried out at the Biotech Center Laboratory of IPB University. Gross energy and minerals (Ca and P) were analyzed at the Feed Science and Technology Laboratory, Faculty of Animal Science, IPB University. Total solubility analysis was carried out at the Dairy Animal Nutrition Laboratory, Faculty of Animal Science, IPB University.

2.2. Material Preparation

Cassava tubers and leaves were harvested from a local farm in Bogor, Indonesia. Cassava tubers were peeled, washed, and sliced. Cassava leaves were separated from their stalks. The sliced cassava tubers and cassava leaves were dried in a dome dryer until the moisture content was <14%, and grinded to flour using a 2 mm screen-size grinder. The dome drying temperature is around 50 ℃

Palm kernel meal was obtained from the Feed Industry Laboratory, Faculty of Animal Science, IPB University. The palm kernel meal was grinded and sieved using a grinder without a screen (30 mesh).

Moringa leaves harvested from the area of the Faculty of Animal Science, IPB University. Moringa was extracted with an osmotic extraction procedure using brown sugar cane in a ratio of 1:1. The mixture was stored and sealed in a plastic box for 7 days. Moringa extract was obtained after squeezing the mixture. Moringa by-product was dried in the oven and grided to flour using a 2 mm screen size grinder. The oven drying is about 80 ℃.

Dry peeled corn was obtained from the Feed Industry Laboratory, Faculty of Animal Science, IPB University. The corn was grinded to ground corn using a 3 mm screen-size grinder.

2.3. Cassamore Production

Cassamore consists of 4 feed ingredients: cassava flour, palm kernel meal, cassava leaf flour, moringa extract and moringa by-product. The nutrient content of the feed ingredients used in cassamore production is shown in Table 1.

Table 1. Nutrient content of feed ingredients

Feed ingredients	Nutrients							
	DM	Ash	CP	EE	CF	NFE	Ca	P
Cassava flour1	84,13	2,44	3,60	0,44	0,48	77,18	0,01	0,03
Cassava leaf flour2	91,40	8,47	25,37	11,77	10,63	35,16	-	-
Palm kernel meal (sieved)	93,95	6,24	16,23	11,59	13,38	46,51	-	-
Moringa leaves3	95,16	9,04	24,94	11,50	4,80	44,84	4,22	0,25

[1] Fagbohun dan Lawal (2014), [2] Abu *et al.* (2014), [3] Mgbemena dan Obodo (2016)

Using information from Table 1 as nutrient information in the formulation, Cassamore is formulated to have a nutrient composition equivalent to corn. The following is the composition and nutrient content of cassamore and ground corn, which can be seen in Table 2.

Cassava flour, leaf flour, palm kernel meal, and moringa by-products were weighed, mixed and steamed. Cassamore was steamed at 3 ATM pressure in the mixer. the start temperature is 50 ℃ and it is increase until 110 ℃. The cassamore was steamed for 0 (P1), 5 (P2), and 10 minutes (P3). Steamed cassamore was aerated until the temperature decreased, then the cassamore was added to moringa extract and mixed. Furthermore, the cassamore was dried in a dome dryer until the moisture content decreased by 12%. The dried cassamore sample was taken for analysis in the laboratory. The flow of cassamore production is shown in Figure 1.

Table 2. Composition of ingredients and nutrients content

Feed Ingredients	Cassamore (%)	Corn (%)*
Cassava flour	70,00	-
Cassava leaves flour	10,00	-
Palm kernel meal	18,00	-
Moringa by-product	1,00	-
Moringa extract	1,00	-
Corn	-	100,00
Total	100,00	100,00
Nutrients		
Dry matter	86,85	88,69
Ash	3,86	1,09
Crude protein	8,48	7,78
Ether extract	3,80	4,95
Crude fiber	3,90	4,52
Nitrogen-free extract	66,81	70,35
Ca	0,09	0,01
P	0,03	0,38

*Murningsih et al. (2019)

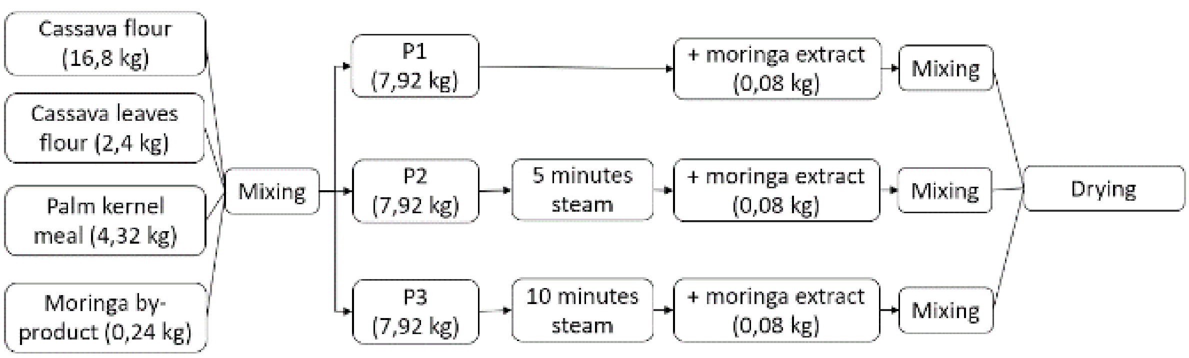

Figure 1. The flow of cassamore production

2.4. Analysis of Physical Properties

Bulk density, tapped density, and specific density were measured using the method referred to [13]. Method of measuring the angle of repose is referred to [14]. Particle size was measured using the [15] method.

2.5. Analysis of Total Solubility

The Total solubility of corn and cassamore was determined by procedure referred to [16].

2.6. Analysis of Chemical Properties

The proximate analyses were carried out to measure ash, crude protein, and ether extract content using the [17] method. Crude fiber content was measured using the method by [18]. The difference method calculated the nitrogen-free extract by deducting the sum of the percentages of ash, crude protein, ether extract and crude fiber content from 100. Gross energy was determined using a bomb calorimeter. Calcium content was measured using the [17] method. Phosphorus was measured using the gravimetric method.

2.7. Statistical Analysis

Data on bulk density, tapped density, angle of repose, particle size, specific density and total solubility were analyzed by completely randomized design (CRD) with 4 treatments and 4 replications by 8 kg per replicate. Significant differences among the means were determined by analysis of variance (ANOVA) using SPSS software version 25. The treatment means with significant differences at $P<0.05$ were compared using Duncan's new multiple-range procedure. Data on ash, crude protein, crude fat, crude fiber, NFE, gross energy, calcium and phosphorus were analyzed descriptively.

3. Results and Discussion

3.1. Physical Properties

The results of corn and cassmore physical properties are presented in Table 3.

3.1.1. Bulk Density

The bulk density value is interpreted as the external volume, including the feed material and air that fill up that volume. Measurement of bulk density is useful for determining the volume occupied by feed ingredients in storage spaces. The value of bulk density is affected by chemical composition [19].

The treatment made a significant difference in the bulk density ($P<0.05$). The bulk density value of ground corn is higher than cassamore, because cassamore has higher crude fiber content than corn. [20-21] reported fiber content has negative correlation with bulk density. In addition, bulk density is also affected by particle size. Particle size has a negative correlation with bulk density, as reported by [22]. Adding steam significantly increased the bulk density in the cassamore ($P<0.05$). Cassamore without steam had a lower density than steamed cassamore. This is caused by reducing air molecules in the feed ingredient particles. Steaming can remove air molecules from starch granules, increasing the material's density [23]. This resulted in P2 and P3 cassamore being more efficient in storage because they required a smaller volume than P1. In Table 3, P2 had a significantly lower bulk density than P3 ($P<0.05$). This shows that the longer the steam delivery time, the higher the bulk density value. This is presumably because the longer the steaming time, the more air molecules are released from the starch granules.

3.1.2. Tapped Density

Tapped density is the ratio of the mass and volume occupied by the material after compaction. The compaction process causes the tapped density value to be greater than the bulk density due to the reduced air voids between the material particles. Analyzing tapped density is to determine the volume occupied by a feed ingredient after the compaction process. Tapped density has a positive correlation with bulk density [24].

Table 3. Physical properties of corn and cassamore

Parameter	Treatment			
	P0	P1	P2	P3
Bulk density (kg m^{-3})	$584{,}04 \pm 8{,}40^{d}$	$344{,}43 \pm 6{,}65^{a}$	$359{,}29 \pm 2{,}48^{b}$	$375{,}64 \pm 4{,}87^{c}$
Tapped density (kg m^{-3})	$695{,}82 \pm 12{,}32^{c}$	$536{,}92 \pm 2{,}41^{a}$	$572{,}99 \pm 12{,}19^{b}$	$582{,}88 \pm 16{,}45^{b}$
Angle of repose (°)	$25{,}80 \pm 0{,}62^{a}$	$42{,}79 \pm 1{,}94^{b}$	$44{,}99 \pm 0{,}69^{c}$	$44{,}62 \pm 0{,}93^{c}$
Particle size (μm)				
Dgw	$944{,}83 \pm 31{,}62^{a}$	$1070{,}64 \pm 45.97^{b}$	$1079{,}44 \pm 38{,}07^{b}$	$1077{,}16 \pm 32{,}22^{b}$
Sgw	$1{,}06 \pm 0{,}35^{a}$	$9{,}35 \pm 0{,}41^{b}$	$9{,}27 \pm 0.33^{b}$	$9{,}29 \pm 0{,}29^{b}$
Spesific density (g cm^{-3})	$1{,}23 \pm 0{,}04^{a}$	$1{,}34 \pm 0{,}07^{b}$	$1{,}38 \pm 0{,}06^{b}$	$1{,}40 \pm 0{,}05^{b}$

P0 = ground corn; P1 = cassamore without steam; P2 = cassamore with steam 5 minutes; P3 = cassamore with steam 10 minutes
Different superscript on the same line indicates significantly different $p<0{,}05$

The results showed a significant difference in the treatment of the tapped density value (P<0.05). As seen from Table 5, ground corn (P0) had a higher tapped density than cassamore (P1, P2, and P3). Ground corn (P0) contains less fiber than cassamore (P1, P2, and P3). The lower the fiber content, the higher the tapped density value [20]. This resulted in cassamore being bulkier than corn. Test results show that steaming can increase tapped density value of cassamore. Tapped density value for cassamore without steam was significantly lower than the steamed cassamore (P<0.05). It is probably caused by the release of air in the feed ingredients, which can increase density. This resulted in the steamed cassamore being more efficient in storage and transportation because it requires a smaller volume to accommodate the material at the same mass after compaction. A higher tapped density value requires a smaller volume of space for storage

3.1.3. Angle of Repose

The angle of repose needs to be determined because it is closely related to the flowability of the feed ingredients. The angle of repose indicates the minimum degree of slope for the feed material to flow. The smaller the angle of repose, the easier it will be for the material to flow. The angle of repose is divided into 5 categories: very easy to flow (25-30°), easy to flow (30-38°), medium (38-45°), difficult to flow (45-55°) and very difficult to flow (>55°) [25].

The results showed that treatment significantly affected the angle of repose (P<0.05). Based on the results, ground corn had a significantly smaller angle of repose than cassamore (P<0.05). Many factors can cause this. The angle of repose is affected by geometrical properties, particle size, coefficient of friction, number of particles, moisture content, airflow, and measurement methods [26]. This causes corn to be classified as flowability, which is very easy to flow, while cassamore is classified as medium flowability. Steaming increased the angle of repose on the cassamore. As seen in Table 3, P2 and P3 had a significantly higher angle of repose than P1 (P<0.05). This resulted in the cassamore P2 and P3 requiring a larger angle to flow. However, Cassmore P2 and P3 are still classified as having moderate flowability (38-45°). Based on Table 3, the steaming duration did not affect the angle of repose between 5 minutes (P2) and 10 minutes (P3) of steaming duration. This resulted in cassamore P2 and P3 requiring the same angle to flow.

3.1.4. Particle Size

Particle size, according to [15], can be presented in geometric mean diameter (Dgw) and geometric standard deviation (Sgw) forms. Dgw is analyzed to determine the average value of the material particle size in micrometer units. Particle size plays a role in facilitating the mixing of feed ingredients and the level of homogeneity [27].

The results of the ANOVA analysis showed that the treatment provided a significant difference (P<0.05) in the particle size. As seen in Table 3, ground corn (P0) had a significantly lower Dgw than cassamore (P<0.05). The particle size is greatly influenced by the diameter of the screen holes used in the grinder. The use of smaller screen holes will produce smaller products. Ground corn (P0) was ground using a 3 mm screen, while the ingredients for cassamore were ground using a 2 mm screen. However, the Dgw presented in Table 3 shows the opposite result. This is probably because cassamore is made using different materials. Although the cassamore ingredients are ground using a uniform screen (2 mm), the resulting particle size can vary depending on the type of feed ingredient. This affects the overall particle size of the cassamore. The particle size between P1 cassamore with P2 and P3 cassamore showed no significant difference (P>0.05). This contradicts [28], who state that increasing steaming time can increase particle size. This is presumably because the steaming duration did not affect the increased particle size.

The Sgw value analysis aims to determine the level of uniformity or variation in particle size in the material. ANOVA analysis significantly affected particle size (P<0.05). Cassamore had a significantly higher Sgw value than ground corn (P<0.05). A large Sgw value indicates a less uniform particle size. The higher the Sgw value, the lower level of uniformity [29]. This shows cassamore had a lower level of particle uniformity than ground corn. Based on the test results in Table 3, the addition of steam and the time of application of steam did not have a significant effect (P>0.05) on the uniformity level (Sgw) of the cassamore.

3.1.5. Specific Density

Specific density is the ratio of mass to volume of the material. Measurement of specific density plays a role in determining bulk density, threshold power, homogeneity when mixing, and accuracy in automatic dosing processes in feed factories [19].

Based on the results, the treatment had a significant effect (P<0.05) on specific density. Cassamore had a significantly higher specific density than ground corn (P<0.05). This is due to the fact that cassamore ingredients have a higher specific density than ground corn. Cassava flour had a specific density of 1.48 g/cm3 [30] and palm kernel meal 1.53 g/cm3 [24]. Different specific density values can be affected by differences in the surface characteristics of the particles and the nutrients contained [13]. The results also showed that the steam treatment had no significant effect (P>0.05) on the specific gravity of the cassamore.

3.2. Total Solubility

The total solubility value needs to be determined to indicate the level of utility. The results of the total solubility analysis can be seen in Figure 2. Based on the results, the treatment did not significantly affect total solubility (P>0.05). Corn (P0) had a total solubility of 16.00%, while the total solubility of cassamore was 14.24% (P1), 14.85% (P2), and 14.96% (P3). Solubility is affected by the type of carbohydrates that make up the material [32]. One type of carbohydrate, namely starch, is a polysaccharide consisting of amylose and amylopectin. Cassamore, mostly made from cassava, has a ratio of amylose and amylopectin of 1:3.18, while corn is 1:2.05 [5]. Steaming duration can degrade amylopectin into smaller molecules such as amylose and other simpler structures [33]. Therefore, the ratio of amylose to amylopectin will change with steaming duration. A high content of non-starch polysaccharides will cause low solubility of these water materials [31]. However, the total solubility values of corn and cassamore are relatively the same.

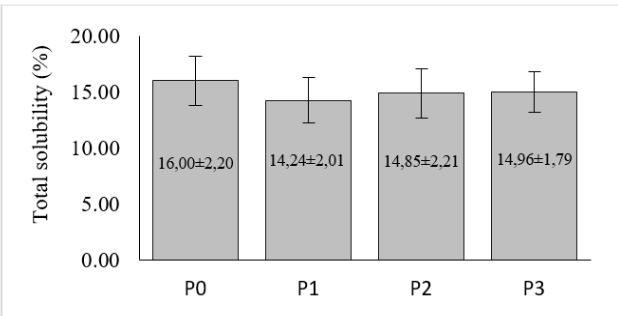

Figure 2. Total solubility results

3.3. Chemical Properties

Chemical properties were analyzed to determine the nutrients contained in corn and cassamore. The results of the analysis of the chemical properties of corn and cassamore are presented in Table 4.

3.3.1. Ash

The ash level in feed ingredients needs to be determined because it shows how many minerals are contained in a material. Minerals have an important role in livestock metabolic processes [33].

Based on the proximate analysis results, corn's ash content is 1.78% (P0). This content is less than cassamore, namely 2.78% (P1), 2.90% (P2), and 2.95% (P3). The higher ash content in cassamore is caused by the use of palm kernel meal, cassava leaves, and moringa, which are high in ash, based on Table 1. The higher the ash content, the more mineral content there is in the material. This is consistent with the results of cassamore's calcium (Ca) and phosphorus (P) analyses, which were higher than corn.

3.3.2. Crude Protein

Crude protein content shows all substances containing nitrogen (N), including pure and non-protein nitrogen compounds (NPN). Crude protein content in a feed ingredient must be analyzed because it is an important nutrient for livestock. Protein plays a role in meeting basic life needs, growth and repair of body tissues.

As seen in Table 4, the crude protein content in corn (P0) is 7.26%. in comparison, the protein content in cassamore was 8.21% (P1), 7.91% (P2) and 8.11% (P3). These results also indicate that the crude protein content is relatively the same in casssamore treated with steam or not. Protein in feed ingredients will experience denaturation and change in structure to a simpler structure after steaming [34].

3.3.3. Ether Extract

Ether extract consists of fatty acids, glycerol and fat-soluble vitamins contained in the ingredients. Information about the ether extract content in a feed ingredient is important because fat is an energy source. Fat also plays a role in absorbing vitamins A, D, E and K, which are classified as fat-soluble.

Table 4. Result of analysis of chemical properties (dry matter basis)

arameter	Treatment			
	P0	P1	P2	P3
Ash (%)*	1,78	2,78	2,90	2,95
Crude protein (%)*	7,26	8,21	7,91	8,11
Ether extract (%)*	3,02	3,79	3,34	3,22
Crude fiber (%)*	2,38	6,20	5,95	6,27
Nitrogen-free extract (%)*	85,55	79,02	79,91	79,46
Gross energy (kkal/kg)**	4326	4131	4146	4057
Calsium (%)**	0,55	0,49	0,50	0,47
Phosphorus (%)**	0,22	0,36	0,38	0,40

*Results of IPB Biotech Center Laboratory analysis

**Results of analysis of the Feed Science and Technology Laboratory, Faculty of Animal Husbandry, IPB

As seen from Table 4, the ether extract content in corn is slightly lower than cassamore's, which is 3.02 (P0). In comparison, cassamore had an ether extract content of 3.79% (P1), 3.34% (P2) and 3.22% (P3). The longer the steam is given, the ether extract content in cassamore tends to decrease. This is in line with another study which states that the steaming process can reduce the ether extract content due to molecular damage [34]. The heating process causes rapid movement of the fat molecules. This results in an unstable fat condition that is easily oxidized and hydrolyzed [35].

3.3.4. Crude Fiber

Crude fiber can be interpreted as organic substances insoluble in acid and alkaline solutions, including lignin, cellulose, hemicellulose, chitin, and pentosan. Crude fiber content is one of the limiting factors in animal feed, especially chicken. Fiber is a carbohydrate that is difficult for monogastric livestock to digest but has a role in the development of the digestive organs, speeds up the rate of digestion, and regulates intestinal work [36].

Based on the analysis results, the crude fiber content in cassamore was 6.20% (P1), 5.95% (P2), and 6.27% (P3). This level is higher than corn (P0), 2.38%. This is caused by the use of palm kernel meal and cassava leaf flour in cassamore, which contain quite a lot of fiber. Palm kernel meal contains 13-20% crude fiber [38]. Meanwhile, cassava leaves contain 10.63% crude fiber [10]. Steam treatment can significantly increase the digestibility value of crude fiber in feed [38].

3.3.5. Nitrogen-free Extract

Nitrogen-free extracts are non-structural carbohydrate fractions easily digested, including sugars, starch, pentoses, and other constituents. It is important to know the level of Nitrogen-free extract in feed ingredients because it is closely related to meeting the energy needs of livestock.

The nitrogen-free extract content in corn (P0) is 85.55%. Meanwhile, cassamore contained a lower Nitrogen-free extract than corn (P0), namely 79.02% (P1), 79.91% (P2), and 79.46% (P3). One of the constituent components of Nitrogen-free extract, namely starch, undergoes gelatinization when exposed to heat and water during the steaming process. Gelatinization is a condition in which starch is exposed to high temperatures accompanied by water, which makes the starch granules disintegrate into shapelessness. This makes starch molecules easier to digest by the α-amylase enzyme [39].

3.3.6. Gross Energy

Gross energy is also known as the heat of combustion, which can be interpreted as the amount of heat energy produced from the combustion process using oxygen in a bomb calorimeter.

Based on the test results, corn (P0) contains a gross energy of 4326 kcal/kg. The gross energy content is lower when compared to [34], which states that corn had a gross energy of 4430 kcal/kg. The gross energy content of cassamore cannot be equal to corn's. Cassamore contains gross energy of 4131 (P1), 4146 (P2), and 4057 (P3) kcal/kg. This is because the ash content in cassamore is higher than in corn. Ash belongs to the inorganic compounds in the material. The value of gross energy is determined by organic compounds in the form of proteins, fats, and carbohydrates [40].

The gross energy content cannot yet reflect the amount of energy that livestock can utilize. Therefore, gross energy cannot be used as a benchmark in assessing energy sources for feed ingredients. Metabolic energy is more appropriate for assessing feed ingredients as energy sources, especially in poultry. Metabolic energy results from reducing gross energy with the energy contained in feces and urine [41]. The metabolic energy contained in corn is 3350 kcal/kg [42], while cassava is 3279 kcal/kg [43]. The gross energy of the cassamore is lower than that of corn if P1, P2 and P3 samples contain more protein, fat and much more fiber than the corn sample. This may be due to the higher inorganic content of casmore than corn.

3.3.7. Calcium

Calcium is a macromineral and an essential component livestock needs for bone formation, maintenance of bone structure, and eggshell construction [42]. In addition, calcium also plays a role in forming blood, regulating body tissue systems, and forming eggshells in laying hens [44]. Therefore, it is necessary to know the calcium content of feed ingredients.

Based on the results of the analysis in Table 4, the calcium levels between corn and cassamore were 0.50 (P0), 0.49 (P1), 0.50 (P2), and 0.47 (P3). These results show that corn and cassamore have relatively the same calcium content.

3.3.8. Phosphorus

Phosphorus belongs to the macro minerals that play an important role in bone mineralization. The phosphor measured in this study was total phosphor from corn and cassamore.

Based on Table 4, corn (P0) contains 0.22% phosphor and cassamore contains 0.36% (P1), 0.38% (P2), and 0.40% (P3) phosphor. Phosphor contained in cassamore is slightly higher than that in corn. In addition, the phosphor content tends to increase with increasing steam treatment duration. However, the phosphor content in cassamore was slightly different between treatments.

4. Conclusions

Based on the research results, cassamore containing palm kernel meal had different physical properties from corn. Steam application increases the bulk density, tapped density, and angle of repose in the cassamore. Although the total solubility value can not represent a material's digestibility level, the total solubility value of cassamore is the same as that of corn and cannot be increased by steaming duration. Cassamore had nutritional equivalents to corn, but had higher crude fiber and slightly lower energy.

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