Comparison of Field-Drying, Sun-Drying, and Autoclave-Oven Drying on the Physical Quality of Corn for Poultry Feed

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Abstract. This study aimed to evaluate the effects of different drying methods on the physical characteristics of corn, including moisture content, water activity (aw), and bulk density as indicators of feed quality for poultry. Three drying methods were compared: (1) field-dried corn, representing naturally dried grain harvested from farmers; (2) sun-dried corn, dried directly under sunlight after shelling; and (3) autoclaved + oven-dried corn, representing a controlled thermal treatment. The experiment was arranged in a completely randomized design with three treatments and six replications. Measured parameters included moisture content (% wet basis), water activity (aw), and bulk density (g/L). Data were analyzed using one-way ANOVA and significant differences among treatments were further tested using Duncan Multiple Range Test. The results showed that the drying method had no significant effect on moisture content (11.90–12.98%) and aw (0.712–0.799; $p > 0.05$). The lowest aw value was found in sun-dried corn, indicating better storage stability and feed safety. Bulk density was significantly affected by the drying method ($p < 0.001$). The highest density value was obtained in field-dried corn (775.83 ± 8.42 g/L), while the autoclave-oven treatment reduced the density (755.17 ± 7.19 g/L) due to an increase in material porosity. In conclusion, combination of autoclave and oven drying can be recommended as an effective method for reducing the moisture content and water activity of corn without compromising its physical quality, making it suitable for use as a feed ingredient for broilers with more assured quality.
Keywords: bulk, corn, density, poultry, water activity

1 Introduction

Feed is an important component in livestock farming, as it contributes around 60-70% of the total production costs [1]. One factor that needs to be considered and plays an important role in the success of a broiler farming business is the quality of the feed ingredients, as it can

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affect growth, feed conversion efficiency, and livestock productivity. The main raw material in broiler feed formulation is corn (*Zea mays L.*) which is the main source of energy and is widely used because it contains high carbohydrates, is easily digested and is preferred by livestock [2]. However, the physical and chemical quality of corn is greatly influenced by post-harvest handling, especially the drying method used [3]. The quality of corn as a feed ingredient depends on moisture content, water activity (aw), and density to determine shelf life and the risk of microbial growth during storage. High moisture content and water activity in feed ingredients provide a favorable environment for microbial growth, which can lead to the production of mycotoxins that are harmful to poultry consuming contaminated feed.

In general, farmers in Indonesia still use natural drying methods with sunlight because they are considered cheap, simple, easy to do, and do not require special equipment. The disadvantages of this drying method depend on weather conditions, temperature instability, and the potential for contamination by dust and microorganisms, which cause corn to produce uneven moisture content and low feed quality. Excessively high moisture content (>14%) can trigger mold growth, physical and nutritional damage, and the emergence of toxins and mycotoxins that can reduce the quality and safety of feed [4].

To overcome these limitations, various modern and efficient drying technology innovations have been developed to produce feed materials with more stable and safer quality. An alternative method that has the potential to improve feed efficiency and quality is the use of controlled drying technology that combines an autoclave and an oven. An autoclave is a thermal technology that works with high-pressure steam at a temperature of 121°C. This technology can inactivate pathogenic microbes, destructive enzymes, and anti-nutritional factors such as trypsin inhibitors [5]. Further treatment involves using an oven at a temperature of 60-70°C, which is expected to accelerate drying, reduce the moisture content to the ideal standard without reducing the nutritional content. Based on the Indonesian standard for animal feed quality (SNI) 4483:2013, the maximum moisture content of corn that meets the standard for feed is 14%. The application of a combination of autoclave and oven is expected not only to accelerate drying time but also to improve energy efficiency, feed safety, and the physical quality of corn. This technology has great potential for implementation on an industrial feed scale as well as a farmer scale, as an effort to increase the added value of local raw materials.

A number of studies have reported the effect of drying methods on corn quality, with most studies focusing only on natural drying or single mechanical drying. Studies that directly compare traditional drying methods (field-drying and sun-drying) with controlled drying technology based on a combination of autoclave and oven on the physical characteristics of corn as poultry feed are still limited, especially in the context of conditions and practices of farmers in Indonesia. This study offers a novelty in the form of a direct and systematic comparison between traditional drying methods commonly used by farmers and controlled drying methods based on a combination of autoclave and oven, as well as an evaluation of the physical characteristics of poultry feed corn (moisture content, aw, and density).

Based on the above description, this study was conducted to analyze the effect of different drying methods, namely Field-Drying, Sun-Drying, and Autoclave-Oven Drying, on the physical characteristics of corn, including moisture content, water activity (aw), and density. The results of this study are expected to provide scientific information and recommendations for efficient, safe, and applicable drying technology in the processing of broiler feed quality.

2 Materials and Methods

2.1 Research materials

The main ingredient used in this study was corn (Zea mays L.) obtained from local farmers in the Pasuruan region of East Java. The corn used was uniformly ripe and free from fungal contamination. Prior to the drying process, all samples were cleaned manually to remove dirt, corn husks, dust, and damaged corn kernels.

The equipment used in this research includes:

1) Autoclave for pressure heat treatment (121°C, 1.5 psi for 15 minutes).
2) Drying oven for further drying after autoclaving (60-70°C for 2 hours).
3) Moisture digital analyzer to measure moisture content (% wet basis).
4) Measuring cylinder and digital scales to determine mass density (bulk density, g/L).

All materials and equipment are prepared under clean and controlled laboratory conditions to minimize variations due to environmental factors.

2.2 Research methods

This study used a Completely Randomized Design (CRD) with three treatments and six replications (18 experimental units). Each replication consisted of 5 kg of corn derived from the same initial batch. The replications therefore represent independent experimental units processed and analyzed separately, rather than subsamples taken for repeated measurements from a single experimental unit.:

T1: Field-dried corn

Corn was dried naturally in the field, as is common practice for farmers. The cobs were left on the plants until their moisture content reached approximately 20–25%, then harvested and hulled using a hulling machine. This treatment represents traditional post-harvest handling methods and served as the primary comparison. Samples were taken from each sack at six points: the top right, top left, middle right, middle left, bottom right, and bottom left.

T2: Sun-dried corn

The corn kernels are spread evenly on a clean tarp and dried in direct sunlight for 2–3 days at an ambient temperature of around 30–35°C. The layer is kept at a thickness of around 2–3 cm and turned every 3 hours to ensure even drying. This treatment illustrates a simple, low-cost drying method commonly used by livestock farmers and feed producers in tropical regions.

T3: Autoclaved + oven - dried corn

Corn kernels are autoclaved at 121°C and 1.5 psi for 15 minutes to modify the starch and protein structure through heat and pressure. Next, the corn is dried in a oven at 60-70°C for 2 hours until the moisture content stabilizes. This treatment represents a controlled thermal drying process that has the potential to improve the digestibility and microbiological safety of feed ingredients.

Observed Parameters

The physical characteristics of corn are evaluated through three main parameters, moisture content (% wet basis), water activity (aw), and bulk density (g/L). These three parameters are important indicators for assessing drying efficiency, storage stability, and physical integrity of corn as a broiler feed ingredient.

1) Moisture content (% wet basis)

   Moisture content measurements were performed using a grain moisture tester (digital moisture meter for grains). Approximately 100 grams of corn kernels were placed in the measuring chamber of the device, and readings were taken after the device reached equilibrium.

The measurement results were automatically displayed as a percentage of moisture content based on wet weight (%). Each measurement was performed three times for each repetition, and the average value was used for data analysis.

Low moisture content indicates effective drying and is an important factor in preventing mold growth and maintaining stability during storage. In this study, the safe moisture content for feed storage was set at 11–13%, which is considered ideal for suppressing microbial activity.

2) Water Activity (aw)

Water activity is measured using an empirical method based on a linear relationship between moisture content and water activity. The Aw value is calculated based on a regression equation developed from previous moisture content test results.

The water activity value is calculated using the formula:

$$Aw = 0.08 \times \text{Moisture content (\%)} - 0.24$$

aw value indicates the amount of free water available for microbial growth and chemical reactions within the material. Corn with an aw value below 0.75 is generally resistant to mold growth, while values above this limit increase the risk of spoilage due to microbial activity. This parameter complements moisture content measurements because it reflects the stability and safety of feed ingredients during storage.

3) Density (g/L)

Density was measured using a volumetric method. A total of 1000 mL of corn kernels were placed into a measuring cylinder without pressing, then weighed using an analytical balance and calculated using the formula.

The density value is calculated using the formula:

$$\text{Density (g/L)} = \frac{\text{Mass (g)}}{\text{Volume (L)}}$$

This parameter describes the density, porosity, and physical structure of corn grains. Changes in density can indicate physical modifications due to heat treatment, such as increased porosity or starch gelatinization during the drying process.

2.3 Data analysis

Statistical Analysis

Observation data were analyzed using a Completely Randomized Design (CRD) with three treatments and six replications. Differences between treatments were analyzed using one-way Analysis of Variance (ANOVA). If there is a real difference ($p < 0.05$), then continue with a comparison test using Duncan's Multiple Range Test (DMRT). Data analysis and results are presented as mean±standard deviation (SD). Differences between treatments are indicated by different superscript letters in the results table.

3 Results and Discussion

The results of the study show the effect of drying methods on the physical characteristics of corn as poultry feed, as presented in Table 1. Statistical analysis shows that drying methods have no significant effect ($p > 0.05$) on the moisture content and water activity (aw) of corn, but have a significant effect ($p < 0.05$) on corn density. The difference in density values reflects changes in the physical structure of corn kernels due to different drying treatments, which has implications for the efficiency of feed handling and storage. These three parameters reflect the physical quality of the feed, which is related to shelf life and handling efficiency.

Table 1. Physical characteristics of corn based on drying method

Treatment	Moisture content (% wet basis)	Water Activity (aw)	Density (g/L)
Field dried	12.38 ± 0.36	0.751 ± 0.029	775.83^{a} ± 8.42
Sun-dried	11.90 ± 0.33	0.712 ± 0.026	720.50^{c} ± 9.57
Autoclave + Oven	12.98 ± 1.18	0.799 ± 0.094	755.17^{b} ± 7.19

Different superscripts $^{a-c}$ in the same column indicate significant differences ($P<0.05$).

3.1 Moisture content

Moisture content is one of the important parameters in determining feed quality because it is directly related to shelf life and the risk of damage due to microbial activity. The results of the study are shown in Table 1, which indicates that the moisture content of corn produced by sun-drying, field-drying, and autoclave + oven methods was 11.90 ± 0.33%, 12.38 ± 0.36%, and 12.98 ± 1.18%, respectively. These values indicate that all drying methods have met the feed material moisture content standard, which is ≤ 14% [6].

The sun-drying method produced the lowest moisture content because direct exposure to sunlight increases the evaporation rate, thereby significantly reducing the moisture content during sun-drying [7]. Meanwhile, field drying showed a slightly higher moisture content because the natural drying process in the field depends on weather conditions and environmental humidity. The moisture content in corn kernels can decrease by several percent per day if the conditions are warm, sunny, windy, and dry, but it can also stagnate if the weather is cloudy or humid [8]. The autoclave + oven treatment produces the highest moisture content due to the process of water vapor reabsorption and water binding by gelatinized starch during pressure heating. Autoclaving modifies the starch structure and changes the water retention capacity of corn kernels [9]. High heat on corn can affect moisture content and allow structural changes [10].

3.2 Water activities

Water activity (aw) indicates the amount of free water in a material that can support the growth of microorganisms, chemical reactions, and nutrient degradation processes. The measurement results show that sun-drying has the lowest aw value of 0.712 ± 0.026, followed by field-drying at 0.751 ± 0.029, and autoclave + oven at 0.799 ± 0.094.

The lowest aw value in sun drying indicates that this method is most effective in reducing water activity in corn kernels. Sun drying can reduce moisture content and aw to safe levels when weather conditions (temperature, radiation, relative humidity) are favorable and proper handling is carried out, such as stirring [11]. These conditions result in more stable moisture content and water activity for long-term storage. Field drying produces a slightly higher aw value. This is because the influence of humid or variable outside air humidity can cause an increase in water content or water re-adsorption [12]. Meanwhile, autoclave + oven shows the highest aw value. This is due to the presence of trapped water vapor during the pressure heating process, as well as water binding to the starch structure due to high-temperature-induced gelatinization [13]. Although drying at high temperatures accelerates the decrease in moisture content, this decrease is not always followed by a proportional decrease in aw, as some water becomes chemically bound and cannot be completely evaporated.

3.3 Density

Bulk density describes the mass of material per unit volume that includes the space between corn kernels. A high density value indicates that the corn kernels are denser and more uniform, which is beneficial in terms of storage efficiency, transportation, and feed formulation. Based on the results of the study, the density values showed that field drying (775.83 ± 8.42 g/L) had the highest value, followed by autoclave + oven (755.17 ± 7.19 g/L), and sun drying (720.50 ± 9.57 g/L) had the lowest value.

The High density in field drying indicates that the natural drying process maintains the internal structure of corn kernels without causing expansion due to heat. This is because field drying shows that the natural drying process maintains the internal structure of corn kernels without causing expansion due to heat. Slow drying reduces the internal moisture gradient on the surface, thereby suppressing stress cracking and volume changes, so that the space between kernels is relatively small and the bulk density remains high [7, 12, 14]. An increase in density occurred in the autoclave + oven treatment, indicating that thermal treatment can reduce porosity and improve starch restructuring [15]. This is in line with the opinion [12] that thermal treatment induces partial gelatinization, reduces porosity, and increases dry matter density. Meanwhile, the sun-drying method produces a lower bulk density in corn compared to several controlled drying methods. This is due to uneven drying and changes in internal structure (pore formation, damage or fragmentation) that occur during field drying and post-harvest handling, so that the effective volume per mass increases and the space between grains becomes larger [5].

4 Conclusion

Based on the results of the study, sun-drying produces the lowest moisture content and water activity, indicating the effectiveness of this drying method in reducing moisture and increasing the storage stability of feed materials. The field-drying method showed the highest density, reflecting a more compact and uniform grain structure due to the slow natural drying process and minimal damage to the internal structure. The autoclave + oven method produced the highest moisture content and water activity due to water vapor binding during pressurized thermal heating and starch gelatinization, but this method is considered to kill bacteria and inhibit microbial growth. Differences in thermal and environmental conditions in each drying method affect water evaporation capacity, starch structure changes, and corn physical properties, thereby determining quality, shelf life, and efficiency of use as feed material. Overall, the combination of autoclave and oven drying can be recommended as an effective method for reducing the moisture content and water activity of corn without compromising its physical quality, making it suitable for use as a feed ingredient for broilers with more assured quality.

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