Research Article

Comparative Proximate Value and Energy of Pidan Powder with Various Production Methods

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Abstract | Pidan, also known as century egg or preserved duck egg, is a traditional Chinese delicacy made by aging duck eggs. This study evaluated the proximate composition and energy value of pidan powder produced using two distinct aging methods. Method A involved immersing duck eggs for 8 weeks in an alkaline solution composed of water (1000 mL), salt (75 g), black tea brew (1:1, w/v), sodium carbonate (40 g), and calcium hydroxide (40 g). In contrast, Method B consisted of a 2-week soaking period in a solution of water (500 mL), salt (38 g), and sodium hydroxide (20 g), followed by 8 weeks of dry aging in a light-proof environment. Pidan powder from Method A exhibited lower moisture (3.62%) and protein (34.35%) but higher carbohydrate (39.74%) and fat (17.83%) content compared to Method B, which produced powder with higher moisture (6.87%) and protein (44.88%) but lower fat (11.44%) and carbohydrate (33.42%) content. Both methods yielded comparable ash content (Method A: 4.46%, Method B: 4.36%) and lower total energy values (Method A: 395.98 kcal/100 g; Method B: 392.24 kcal/100 g) than untreated egg powder (424.65 kcal/100 g). These results suggest that Method A is more suitable for producing dry, energy-dense pidan powder, while Method B is preferable for formulating high-protein, low-fat alternatives.

Keywords | Aging, Duck egg, Alkaline, Traditional egg curing, Nutrient analysis, Preservation

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INTRODUCTION

Pidan (century egg) is a processed duck egg product from mainland China (Hou *et al.*, 2023). The egg is known for its distinctive color, texture, and flavor, making it popular among Chinese people and a favourite in the international market (Fu *et al.*, 2014). The production of pidan involves a preservation process that impacts its physical and chemical characteristics. The aging process in producing pidan can be done through several methods, namely rolling powder, soaking in solution, and coating with dough, and each method takes about 20-45 days to age (Vanmontree *et al.*, 2017). The immersion method in alkaline solution has several advantages due to the economical production cost, easy process, and can produce large quantities at once (Vanmontree *et al.*, 2017).

Chemically, pidan contains lower carbohydrates but higher protein when compared to eggs in general, so in terms of nutrition, pidan is quite suitable as a source of energy when consumed (Ganesan *et al.*, 2014). Pidan also contains vitamins A, B12, B, D, phosphorus, selenium, and iron (Teng *et al*., 2016). Consuming pidan regularly can improve the quality of life, including maintaining appetite, protecting liver function, eye health, moisturizing the throat, relieving body heat, reducing hangovers, preventing inflammation, and cancer (Batool *et al*., 2021). In daily life, pidan is usually consumed directly without cooking as a complementary ingredient in several mandarin dishes such as chicken porridge and dim sum (Cai and Sweeney, 2018).

Physically, pidan has a speckled shell, the white is chewy like dark brown jelly, and the yellow is dark green with a creamy center. Pidan has a creamy flavor with a very sharp ammonia and sulfur aroma (Zhang *et al*., 2018). The unique and distinctive performance of pidan often makes some people think of it as an unusual processed egg, making them reluctant to consume it, even though pidan is a processed egg product with good nutritional quality. Based on this fact, pidan is further processed by freeze-drying technology into a powder preparation like egg flour in general, hoping that it is more practical and convenient for further processing purposes or direct consumption as a functional food.

There have been several ways to produce pidan in the past, including the soaking method in alkaline solution, the Hulidan method, and the Dsaudan method. Hulidan is the coating of egg shells with a mixture of salt, clay, and ash as a coating agent which is then matured for 1 month, while Dsaudan is a 6-month maturing process where a mixture of rice and salt is used as a coating agent (Evanuarini *et al*., 2021; Ganasen and Benjakul, 2011). The differences between the three production methods are expected to impact the quality of the resulting pidan.

This study was conducted to compare powder quality in terms of chemical characteristics (protein, fat, water, ash, carbohydrate and total energy content) as a consequence of different production methods. This study is expected to provide information regarding the best and most suitable pidan production method to be applied in the tropics in general or in Indonesia in particular.

MATERIALS AND METHODS

Materials

The materials used in this study were 100 eggs with a weight range of 55–65 g produced on the same day at the Banyubiru Duck Unit of the Livestock and Animal Health Service Office of Banyubiru District, Semarang Regency, Central Java Province. Eggs were cleaned from dirt attached to the shell and then placed in a dry container at room temperature for further processing. Other materials and instruments were specified in the following sections.

Methods

Production of pidan egg

Pidan is produced by implementing the principle of aging method in an alkaline solution. In this study, the alkaline solution, which acts as an aging medium, was modified into two categories: Methods A and B. As a control, fresh duck eggs without treatment were set. Each category, both control and variation methods, had 6 repetitions. In method A, duck eggs were fully soaked for 8 weeks with the composition of the aging medium consisting of water (1000 mL), salt (75 g), black tea brew (1:1, w/v), sodium carbonate (40 g) and calcium hydroxide (40 g). For method B, the eggs were first soaked for 2 weeks in a aging medium consisting of water (500 mL), salt (38 g), and sodium hydroxide (20 g), followed by 8 weeks of aging in a light-proof place (eggs were wrapped in 2 layers where the first layer was plastic wrap and the second layer was newsprint, then the wrapped eggs were stored in a box). After the soaking period ended, the midges were ready for collection (Figure 1) to be processed to the next stage.

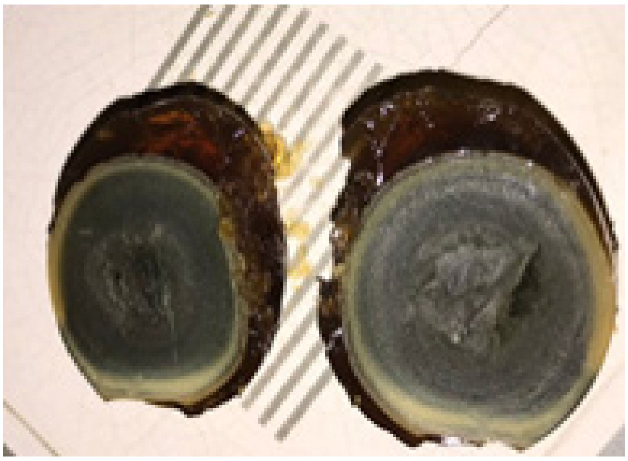

Figure 1: Pidan (century egg) produced from the immersion method in the modified alkaline solution (methods A and B).

Preparation of pidan powder

The preparation of pidan powder was carried out with reference to Adetoro *et al*. (2020) which was modified. The finished pidan was pulverized with a blender and then dried using a freeze dryer for approximately 48 hours at a temperature range of -40 to -50°C. After that, pulverization was carried out using a grinder for 15 seconds until it became powder (Figure 2).

Figure 2: Duck egg powder as control (C) and pidan powder produced from method A and B.

Proximate analysis

Crude protein content

Testing protein levels in pidan eggs was carried out using the Kjeldahl method, referring to Arifan *et al.* (2024), which is divided into three stages, namely the process of destruction, distillation, and titration. In the deconstruction process, the sample was mashed and weighed as much as 1 g and put into the Kjeldahl flask, then, a pipette of 10 mL of concentrated H_2SO_4 was included in the kjeldahl flask. The kjeldahl flask is heated and cooled to produce a clear green color. After cooling, the solution was diluted with distilled water in a 100 mL volumetric flask, distilled water was added to the limit mark, and homogenized. Pipette dilution results in as much as 10 mL and is put in a Kjeldahl flask for distillation.

In the distillation process, 33% NaOH solution was added. The distillate was collected in an erlenmeyer filled with 0.1 N HCl as much as 10 mL and checked using litmus paper until the results showed no alkaline properties. The distillate titration process involves adding five drops of phenolflatelin and titrating it with 0.1 N NaOH standard solution until a pink color is formed. The above procedure was repeated without a sample for the blank. The equivalence point was marked by a change in color from blue-violet to purple. The percentage of protein is calculated by calculating the percentage of the nitrogen element of the sample by reducing the NaOH of the sample with NaOH blank, then multiplying by the N value of HCl and 14.008, then dividing by the weight of the sample multiplied by 1000, the result is then multiplied by 100%. The results must be multiplied by 6.25 as a correction factor.

Crude fat content

Crude fat content testing using the Soxhlet method was carried out based on AOAC (1996). A sample of 2 g was put into a lead and covered with cotton (sample weight). The lead is placed in the soxhlet and heated to a temperature of 135°C for 20 minutes. The aluminum cup and fat were put in the oven for 2 hours at 135°C, then put in a desiccator after it had cooled and the weight of the aluminum + fat was weighed. Fat content is calculated by dividing the total weight of aluminum foil and fat by the weight of the aluminum cup and multiplying by 100%.

Moisture content

Moisture content was tested using the drying method (thermogravimetry) as described in AOAC (1996). Samples were weighed 4-5 g and dried in an oven at 105°C for 4 hours, after which they were weighed to obtain a fixed weight. The moisture content calculation is determined by comparing the weight of water (the difference in the mass of the sample before and after drying) with the initial weight of the sample (the weight of the sample before drying) multiplied by 100%.

Ash content

Ash content was tested using the dry ignition method (Abraha *et al.*, 2017). Samples were weighed as much as 5-10 g in a cup, put into the furnace, heated at 300°C, and then increased to 420-50°C for 5-7 hours. The ash content is obtained by subtracting the weight of the cup and the sample after ignition from the weight of the empty cup and dividing by the weight of the sample, which is then multiplied by 100%.

Carbohydrate content

Carbohydrate analysis can be done using the luff schoorl method (Kurnia *et al.*, 2021). The sample was weighed as much as 5 g in a 100 mL volumetric flask. The sample was taken at 10 mL, entered Erlenmeyer at 250 mL, and then 30% HCl was added. The sample was heated to a temperature of 70-80°C, cooled, and neutralized with 30% NaOH to pH 7. The sample was put in a 250 mL volumetric flask, added with distilled water, and homogenized. Samples were taken 10 mL put in 250 mL erlenmeyer, added 25 mL luff schoorl, then heated until a brick red precipitate. The sample was cooled and 15 mL of 20% KI and 25 mL of 25% H_2SO_4 were added. Titration with Na2S2O3 until light yellow, then added 1 mL of amylum and titrated. The carbohydrate content is calculated by determining the glucose content first by multiplying the glucose contained (mg) by the dilution factor and dividing by the weight of the snippet (mg), which is then multiplied by 100%. Carbohydrate content is obtained by multiplying 0.90 with glucose content.

Total energy

The total energy of pidan eggs in every 1 g is generated from calculating the protein, fat, and carbohydrate calories. The protein, fat, and carbohydrate content is multiplied by 4, 9, and 4 cal, respectively, which is the energy unit for every 1 g of macro components, so that calories are obtained (Aeni *et al.*, 2023). Total energy is obtained by summing the protein, fat, and carbohydrate content, each of which has been multiplied by 4, 9, and 4, respectively.

Statistical analysis

The test data were analysed statistically with a parametric Analysis of Variance (ANOVA) test with a significant level ($p<0.05$), followed by Duncan Multiple Range Test (DMRT) if there was a real effect to determine the difference of the treatment given. Data analysis was conducted using the IBM SPSS for Windows 26.0 series application.

RESULTS AND DISCUSSION

This study tried to compare the proximate values (moisture, ash, carbohydrate, crude protein, and crude fat) and energy of pidan powder produced through 2 different aging methods. The information generated in the comparative study is expected to be used as a reference to determine the most appropriate method to produce good-quality pidan powder in terms of nutritional aspects. To find out more facts related to the nutritional facts of pidan eggs, fresh duck eggs without aging were used as a control in this comparative study.

Proximate value of pidan powder

As shown in Table 1, the aging method affected the proximate value of egg powder produced in this study ($p<0.05$). The production of high shelf-life egg products in this study, namely pidan powder, has involved two essential process stages: Aging and drying. The aging stage, which involves several ingredients (water, black tea brew, salt, sodium carbonate, calcium hydroxide, and sodium hydroxide) with an 8-week aging duration, has changed the chemical characteristics of the egg powder produced, affecting its proximate value. The aging media consisting of salt and other chemicals that are alkaline, once in contact with the egg, then undergo diffusion so that they can penetrate the shell, shell membrane, and albumin until they finally reach the yolk (Matsumoto *et al*., 2021).

Table 1: Proximate composition of pidan powder produced using different aging methods.

Parameters (%)	Production methods		
	Control	A	B
Moisture	3.72 ± 0.27^b	1.86 ± 0.17^c	7.20 ± 0.10^a
Ash	3.60 ± 0.77^b	12.95 ± 1.00^a	12.55 ± 0.34^a
Carbohydrate	4.82 ± 2.48^a	3.04 ± 1.08^b	1.30 ± 0.49^c
Crude Protein	43.21 ± 1.28^b	26.02 ± 0.32^c	61.18 ± 1.10^a
Crude Fat	40.32 ± 0.92^a	40.52 ± 0.45^a	24.49 ± 0.35^b

Data was expressed as mean±standard deviation. Different superscripts in the same line show the significant differences among the groups ($p<0.05$), i.e. duck egg powder as control, pidan powder from A and B methods.

When diffusion takes place, there is a movement of molecules from the high-concentration aging medium to the low-concentration area of the egg, resulting in the proximate values of pidan powder, namely the moisture, ash, crude protein, crude fat and carbohydrate content being different when compared to fresh eggs without aging (Benjakul and Kaewmanee, 2017). Apart from diffusion, at the same time osmosis also occurs where specifically for the solvent component, namely water, through the egg membrane the water moves from an area with a low concentration to a aging medium with a high concentration (Hatta et al., 2023).

Furthermore, pidan powder produced by method A had the lowest moisture content and crude protein among other egg powders. In contrast, method B produced pidan powder with the highest moisture content and crude protein ($p<0.05$). In method A, which involves a longer egg soaking stage in liquid media, osmosis lasts longer, where more water comes out of the egg, causing the pidan powder's moisture content to be much lower (Adekeye *et al*., 2020). Thus, method A is better than method B in producing a quality pidan powder product. The allowable moisture content standard for egg powder/flour products is 8%, because water content above 8% can cause deterioration and damage to the egg flour (Hayuningtyas *et al*., 2022).

Method A involves black tea and calcium hydroxide in the aging medium. The phenol group from the tea tannin compound, as well as calcium hydroxide, can bind and denaturate egg protein molecules, causing the crude protein content of pidan powder to be low, so that it does not comply with the egg flour quality standard for protein content, which is at least 45% (Kilmister *et al*., 2016; Pin *et al*., 2022; Santiago-Ramos *et al*., 2018; UNECE, 2010). On the other hand, in method B, because there is no black tea and calcium hydroxide in the composition of the aging medium, the resulting pidan powder has the highest crude protein content. Thus, method B is better than method A for producing protein-rich pidan powder products.

In terms of ash content, the aging process produces higher ash content than fresh egg powder ($p<0.05$). Both methods A and B involve mineral salts in the aging medium that diffuse into the egg to increase the ash content of the pidan powder produced. Variations in mineral salts used in each method did not affect the ash content of pidan powder. Thus, both methods can produce pidan powder with mineral-rich qualities.

The process of aging eggs produces egg powder with lower carbohydrate levels ($p<0.05$). Method B produces pidan powder with lower carbohydrate content than method A ($p<0.05$). The other nutritional content in processed food influences the product's high or low carbohydrate content (Afifah *et al*., 2022). Pidan powder produced from method B has a very high protein content, so the balance of other nutritional composition decreases, especially carbohydrates.

The aging process which involves certain specifications in the aging media, will apparently affect the crude fat content of the product ($p<0.05$), however method A produces the same crude fat content of pidan powder as fresh egg powder, even though on the other hand the crude fat of pidan powder produced method B appears much lower. Method A uses a salt component with a higher concentration that will damage the egg yolk's fat structure, namely low-density lipoprotein (LDL), resulting in more free fat. On the other hand, method B uses sodium hydroxide in the aging medium. As a strong hot base, when dissolved in water, sodium hydroxide can erode the fat contained in eggs so that the fat content of method B pidan powder becomes low (Afrian and Suprayitno, 2019). Thus, method B is very suitable to be applied to produce low-fat pidan powder products.

Energy of pidan powder

The aging method significantly influenced the energy of egg powder (Figure 3). Eggs that are soaked in an alkaline solution and then aged for a certain period (A and B methods) produce egg powder with significantly lower energy than fresh eggs. Curing eggs principally is a storage process that can affect the internal quality of the egg, especially its macronutrient composition (carbohydrates, fats, and proteins), so that it ultimately affects energy calculations (Roberts, 2004). The two methods used to produce pidan eggs, namely methods A and B, produce pidan powder with the same energy content. The total energy value is not different because the calculation is based on the calorific value of protein 4 kcal, fat 9 kcal, and carbohydrates 4 kcal (Aggarwal *et al*., 2016). Increasing the moisture content in a food can affect the decrease in total energy because most of the weight of food comes from water without additional energy (Najjar and Feresin, 2019).

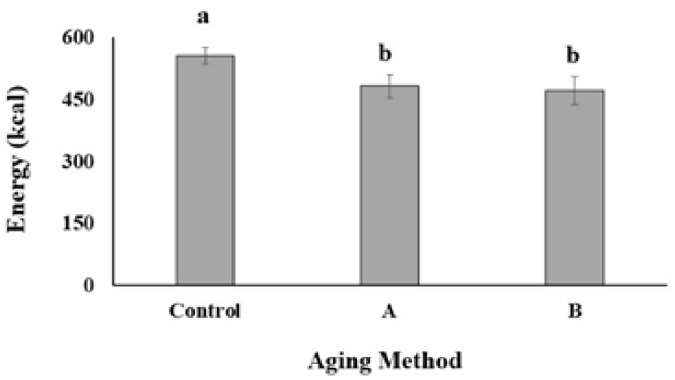

Figure 3: Energy content (kcal/100 g) of pidan powder produced using different methods. Different letters above the bars indicate statistically significant differences among the groups ($p < 0.05$), including untreated duck egg powder (control), Method A, and Method B.

CONCLUSION

This study reveals that the aging method substantially affects the nutritional profile of pidan powder, with Method A (immersion aging with black tea and calcium hydroxide) producing energy-dense powder with higher fat and carbohydrate but lower moisture and protein, while Method B (alkaline soaking followed by dry aging) yields high-protein, low-fat powder suitable for functional food applications. The key innovation lies in demonstrating how specific aging media and conditions modulate nutrient composition, offering practical value for developing tailored, shelf-stable egg-based products. Nevertheless, this study is limited by the absence of sensory, microbiological, and consumer acceptability assessments, as well as the exclusive use of freeze-drying. Future research should investigate alternative drying methods, nutrient bioavailability, sensory properties, and scalability to support industrial application and broader acceptance of pidan powder products.

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NOVELTY STATEMENT

This study provides the first comparative analysis of proximate composition and energy values of pidan powder produced using two distinct aging methods combined with freeze-drying. The novelty lies in demonstrating how variations in aging media and processing conditions can significantly alter the nutritional profile (protein, fat, carbohydrate, moisture, and energy) of pidan powder, thus offering insights for tailoring functional egg-based products with specific nutrient targets. The findings contribute to the development of shelf-stable, protein-enriched, or energy-dense pidan powders suitable for wider food applications and potential industrial adoption in tropical regions.

AUTHOR'S CONTRIBUTION

Siti Susanti, as the first author, was responsible for the conceptualization of the study, project administration, and drafting of the manuscript. Ahmad Ni'matullah Al-Baarri contributed to the supervision of the research, validation of the methodology, and critical revision of the manuscript. Yasmin Aulia Rachma carried out data curation, statistical analysis, and editing of the manuscript. Nuryanto contributed to the nutritional analysis, interpretation of findings, and review of the results. Fahmi Arifan, as the corresponding author, was responsible for the design of methodology, data analysis, provision of resources, and overall supervision of the project. All authors have read and approved the final version of the manuscript.

Generative AI and AI-assisted technology statement

During the preparation of this manuscript, no generative AI tools were used to generate content, analyze data, or draw conclusions. However, Grammarly (an AI-assisted language tool) was employed solely to improve grammar, spelling, and writing clarity in English. The scientific content, interpretations, and conclusions remain the sole responsibility of the authors.

Conflict of interest

The authors have declared no conflict of interest.

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