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# ANALYSIS OF BETA-CAROTENE AND MICROSTRUCTURE OF DUCK NUGGETS USING PROVIT A1 CORNSTARCH AS FILLER

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***Abstract***

*This study aims to determine the levels of beta-carotene, carbohydrates, cholesterol and microstructure of duck nuggets with corn flour filler Provit A1. The method used was an experiment with a complete randomized design (RAL) of 4 treatments and 4 replicates. The treatment in this study was; P10 = Corn Flour Provit A1 10%, P20 = Corn Flour Provit A1 20%, P30 = Corn Flour Provit A1 30% and P40 = Corn Flour Provit A1 40%. Statistical analysis was performed with ANOVA and mean differences were tested using the Tukey test. The observation parameters were beta-carotene content, carbohydrate content, cholesterol content and microstructure by the Electromagnetic Scanning (SEM) method. The results of this study are that Nuggets with a concentration of 20-30% Provit A1 cornmeal provide the best balance between beta-carotene content, a concentration of 20% provides a good balance between protein from duck meat and carbohydrates from fillers, while a concentration of 30-40% Provit A1 cornstarch provides a significant reduction in cholesterol.*

***Key words****: betarotene, cornstarch, duck nuggets, Electromagnetic Scanning method (SEM).*

## INTRODUCTION

Nuggets are one of the processed meat products that are very popular with consumers because of their practicality, delicious taste, and nutritional content. These products typically use fillers such as wheat flour or cornstarch to help shape the desired texture (Gumilar et al., 2011; Hayati et al., 2023). However, the development of food innovation is currently encouraging the use of alternative fillers that not only function as fillers, but also increase the nutritional value of products, one of which is Provit A1 corn flour.

Provit A1 corn flour is a raw material rich in beta-carotene that has the potential to improve the nutritional quality of meat-based food products. The substitution of Provit A1 cornmeal in duck meat-based nuggets provides an opportunity to produce products with better functional value and quality (Ma'ruf et al., 2019). One of the advantages of Provit A1 corn flour compared to other flours is that it contains carotenoids. Carotenoids are one of the natural antioxidants that can dampen free radicals. Carotenoids, such as beta-carotene, alpha-carotene and fucoxanthin are known as free radical scavengers (can cause cell damage that is carcinogenic in nature) (Yan et al., 1999). According to Serlahwaty et al. (2009) that the wrong lifestyle and diet, pollution and ultraviolet rays have increased the amount of free radicals in the body, so the body needs antioxidants such as carotenoids that can help protect the body from free radical attacks by reducing the impact of disease (Parwata et al., 2010). According to Suarni and Yasin (2011), the carotenoid content in corn can be known based on the color of the seeds. The color of corn kernels indicates the content of anthocyanin pigment compounds (anthocyanidins, aglicones, glucosides), carotenoids and others.

The use of 40 grams of Provit A1 corn flour provides the best quality characteristics of free-range chicken nuggets and gives a satisfactory sensation in organoleptic tests (Ma'ruf et al., 2019). The quality of duck nuggets using Provit A1 cornmeal as a filler provides the best results with a maximum moisture content of 16.91%, protein 16.93%, fat content of 11.46%, carbohydrates of 10.21%, and starch of 12.51% which meet the maximum standards and for organoleptic tests provide a satisfactory sensation (Ma'ruf et al., 2024). This study will use Provit A1 corn flour with a level of 10%,

20%, 30% and 40% as fillers in the manufacture of duck nuggets. The variables to be observed are beta-carotene, carbohydrate, cholesterol and microstructure (SEM) levels. Duck meat is chosen as the main raw material because it has a high protein content (21.4%) compared to beef (18.7%), lamb (14.8%) and pork (14.8%) (Srigandono, 1997), but tends to be less used in the food processing industry than chicken meat.

This study aims to determine the levels of beta-carotene, carbohydrates, cholesterol and microstructure of duck nuggets with corn flour filler Provit A1. This research is expected to contribute to the development of processed meat products that are healthier, high-quality, and economically valuable.

## MATERIALS AND METHODS

### 1. Material

The ingredients used to make the nuggets are afkir duck meat in the amount of 1600 g, Provit A1 Corn Flour 400 g, garlic 6.25%, pepper 0.3%, salt 0.3%, ice cubes as much as 25%, food flavor enhancer 0.3%, chicken eggs 10 grains, coconut oil 2 liters, bread flour 1 kg.

### 2. Duck Nugget Making Process

Afkir duck meat in the amount of 1600 is divided into 4 parts, each part is 400 g, ground and put into a food processor then added with ice cubes 100 g, salt 1.2 g, pepper 1.2 g, garlic 25 g, chicken eggs (egg yolk) 3 grains and skimmed milk powder 54 g, food flavor enhancer 1.2 g. Then add A1 Provit corn flour (10%, 20%, 30% and 40%). After all the materials are homogeneous, it is molded in an aluminum container and then steamed for 30 minutes at a temperature of 60-70$^0$C. The steamed dough is cut into 4 x 4 cm pieces. Next, it is greased with egg whites and breadcrumbs. Then it is fried for 5 minutes at a temperature of 170$^0$C, cooled and then analyzed.

### 3. Research Methods

The method used was a complete randomized design (RAL) of 4 treatments and 4 replicates.

The treatment in this study was:

P10 = Corn Flour Provit A1 10 %;
P20 = Corn Flour Provit A1 20%;
P30 = Corn Flour Provit A1 30%;
P40 = Corn Flour Provit A1 40%.

### 4. Observation Variables

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- Sample Preparation

The sample was crushed and then taken as much as 100 grams and extracted with hexane: acetone:ethanol with a ratio of 2:1:1 as much as 200 ml. Then the upper phase is taken and the solvent is vaporized, while the water phase is extracted again until the lower layer is colorless, then the upper phase is evaporated so that a viscous solution is obtained.

- Preparation of 50 ppm β-carotene Master Solution. Weighed 50 mg of pure β-carotene added with ethanol in a 50 ml (1000 ppm) measuring flask. The 1000 ppm master solution is pipetted at 5 ml then ethanol is added in a 100 ml (50 ppm) measuring flask

- Determination of Maximum Absorption Wavelength (λmax) β-carotene

A 50 ppm β-carotene master solution is pipetted at 1 ml then inserted in a 10 ml (5 ppm) measuring flask and ethanol is added to up to 10 ml. After that the absorption is measured by Visible Spectrophotometry at λ 380-780 nm

- Calibration Curve Determination

As much as 0.5 ml; 1 ml; 2 ml; 3 ml; 4 ml and 5 ml were pipetted from a 50 ppm β-carotene master solution put into a 10 ml measuring flask and the volume was sufficient using ethanol up to 10 ml so that concentrations of 2.5 ppm, 5 ppm, 10 ppm, 15 ppm, 20 ppm, and 25 ppm were obtained.

- Determination of β-carotene levels

10 mg of carrot extract was weighed and then dissolved and diluted with ethanol in a 5 ml measuring flask. Then 0.5 ml was pipetted and the volume was sufficient with ethanol in a 10ml measuring flask. Then the uptake was measured by Visible Spectrophotometry at λmax with ethanol as blanks. The β-carotene content in the sample was then determined based on the linear regression equation Y=bX+a.

**Carbohydrate Content**

Weigh 5 Grams of sample in Erlenmeyer (500 ml capacity), add 200ml of 3% HCl, simmer for 3 hours with upright cooler. Cool

and then neutralize with 30% NaOH, add a little $CH_3COOH$ 3% until the solution is slightly acidic. Transfer to a 500 ml measure, then add Aqua destilatta to the limit. Pipette 10 ml into Erlenmeyer 500 ml, add 25ml LS and 15ml distilled water. Heat over flame until boiling for less than 3 minutes, then let it simmer for 10 minutes, then cool in a tub of ice. Once cool, add 15ml of 20% KI and 25 ml of 25% $H_2SO_4$ slowly. Titration with sodium thiosulfate 0.1N, with starch indicator. Perform Blank titration.

Formula: (Blank – Titer) x $N_{Thiosulfate}$ x 10, then see in the Luff Schoorl list how many mg of sugar is contained for ml sodium thiosulfate used.

$$Glucose\ Levels = \frac{W1xFp}{W} x100,\%$$

up to carbohydrate = 0.90 x up to glucose;
W1= sample weight in mg;
W = the glucose contained for the ml sodium thiosulfate used, in mg from the list;
Fp = dilution factor.

**Cholesterol Content**

a. Cholesterol Calibration Curve

A total of 0, 100; 0,200; 0,400; 0,800; and 1.6 ml of a standard 1000 ppm solution, each plus 2 ml of Liebermann-Burchard reagent in a 5 ml flask, rounded to the limit mark with chloroform. The mixture is incubated for 5 minutes. Absorbance is measured at maximum wavelength. Each concentration is made three times, then the linear equation is made by the linear regression method (y = ax + b). The linearity of the calibration curve is seen from the value of the correlation coefficient (r).

b. Cholesterol as much as determination

A total of 50 mg of extract in a 10 ml receiver and dissolved with chloroform to the limit mark. A total of 1 ml of sample solution plus 2 ml of Liebermann-Burchard reagent in a 5 ml flask, rounded up to the limit mark with chloroform. Each mixture is incubated for 5 minutes. Absorbance is measured at the maximum wavelength, the solution is made three replicates.

**Microstructure by Electromagnetic Scanning method (SEM)**

The working procedure of the **SEM method** is the preparation of nugget samples that are fixed first. 3% glutaraldehida material or substance diluted at 0.1 M Buffer Phosphate for 2-4 hours. Then it was washed with 0.1 M Buffer Phosphate with a pH of 7.3, carried out 3 times for 10 minutes. After fixation 2% osmium is added in 0.1 M phosphate buffer for 2-4 hours at room temperature. Then dehydrated with 100% ethanol for 2 times for 15 minutes. It is then dried and coated with gold, and observed on a Scanning Electron Microscope. SEM tool preparation: turn on the switch located next to the tool (SEM) and leave for 30 minutes to heat the tool, set the specimen on the specimen holder. Then press the EVAC/AIR button to enter the air in the specimen chamber. LED light (which is flashing and yellow). To indicate that air has entered the specimen camber then the AIR LED light is on constantly and does not flash again.

**5. Data Analysis**

The data from beta-carotene and microstructure analysis were analyzed using ANOVA (Variant Analysis) to see significant differences between treatments. If there is a significant difference, further tests are carried out by Duncan or Tukey to determine the best treatment.

## RESULTS AND DISCUSSIONS

The results of the diversity analysis showed that the difference in levels had a very significant effect ($P<0.01$) on the content of beta-carotene. The Honest Real Difference Test (BNJ) showed that the 20% level had a very real beta-carotene content ($P<0.01$) higher than the 10%, 30% and 40% levels, while the 30% level has a very real beta-carotene content ($P<0.01$) higher than the 10% level, but it is not significantly different ($P>0.05$) from the 40% level (Table 1).

Table 1. The average values of β-carotene, carbohydrate and cholesterol of duck nuggets with Provit A1 Corn as a filler

| Level (%) | Variable | | |
|---|---|---|---|
| | Betacarotene (µg) | Carbohidrate (%) | Colesterol (%) |
| 10 | 0.057±0.01$^{C}$ | 12.25±0.56$^{d}$ | 0.761±0.01$^{c}$ |
| 20 | 0.111±0.11$^{a}$ | 33.75,±0.56$^{a}$ | 1.234±0.01$^{a}$ |
| 30 | 0.062±0.01$^{b}$ | 19.25±0.56$^{c}$ | 0.817±0.01$^{b}$ |
| 40 | 0.062±0.01$^{b}$ | 30.75±0.56$^{b}$ | 0.738±0.01$^{d}$ |

The level of β-carotene in this study ranged from 0.057 to 0.111 mcg. These results show

that with the addition of corn flour Provit A1 level of 10% has less beta-carotene content, resulting in less provitamin A produced. At the level of 20%, A1 Provit corn flour filler has a beta-carotene content, providing an optimal value. This is supported by the balance between components and nutrients in afkir duck nuggets. Meanwhile, at the level of 30% and 40%, although there is an increase in the amount of corn flour Provit A1 as a filler, is affected the beta-carotene content in duck nuggets, this is caused by the processing process because through steaming and frying which results in increased absorption of beta-carotene so that beta-carotene levels decrease. According to Indriyani et al., (2018) that heating and oxidation result in a breaking reaction in the cojugated double bonds on carotenoid molecules which results in a decrease in carotenoid activity and degradation. Beta-carotene is a natural pigment compound from the carotenoid group that acts as a precursor to vitamin A and has strong antioxidant properties (Paniagua et al., 2015).

At a concentration of 10%, beta-carotene in Provit A1 cornmeal provides a significant increase in nutrient content compared to control (no substitution). Nuggets at this concentration contain moderate amounts of beta-carotene, perfect for providing additional benefits without excessively affecting color or flavor. A substitution of 20% indicates a higher increase in beta-carotene content, with a golden yellow intensity beginning to be seen in the nuggets. The beta-carotene content in this concentration is enough to meet some of the daily needs of vitamin A, especially in children. At a concentration of 30%, the beta-carotene in the nuggets became more significant, providing a greater nutritional contribution. In addition, beta-carotene also acts as an antioxidant that helps extend the shelf life of the product. The natural yellow color of beta-carotene at this concentration is more dominant, but it is still organoleptic acceptable. A substitution of 40% resulted in the highest beta-carotene content among other treatments. The resulting yellow color is more intense, which can affect consumer perception of the product. At this concentration, the beta-carotene content is close to the optimal limit to meet most daily vitamin A needs without giving rise to excessive taste or texture.

Beta-carotene in nuggets is affected by loss during the processing process, namely: Heating during frying can reduce the beta-carotene content due to oxidation (Sani and Setyowati, 2019; Pénicaud et al., 2011). The homogeneity of mixing Provit A1 corn flour with other ingredients plays an important role in determining the final beta-carotene content in the nuggets. The use of Provit A1 corn flour as a filler in duck nuggets has been proven to significantly increase the beta-carotene content of the product, along with the increase in flour concentration. The optimal concentration can be adjusted based on the consumer's preference for the desired color, flavor, and nutritional benefits. Nuggets with a concentration of 20%-30% Provit A1 cornstarch provide the best balance between beta-carotene content, organoleptic quality, and consumer acceptance.

The beta-carotene content recorded in the samples with 10% corn flour was 0.057 µg. This shows that nuggets containing 10% corn flour have the lowest concentration of beta-carotene. At the 20% level, the beta-carotene content increased to 0.101 µg. This shows that with an increase in the percentage of corn flour, more beta-carotene is added to the mixture which will be found in the final product. At the 30% and 40% levels, the beta-carotene content dropped again to 0.062 µg. Bacchetti et al., (2013) shows that despite the higher cornstarch content, the possibility of interactions or effects of other components in the dough that inhibit the absorption or stability of beta-carotene could explain this decrease. Beta-carotene levels tend to increase with increasing cornstarch percentage up to 20%. This suggests that cornstarch is a valuable source of beta-carotene. At higher percentages (30% and 40%), if beta-carotene levels decrease, this may be due to interactions between the other components in the nugget (such as protein, fat, or binders) that may affect beta-carotene bioavailability (Ma'ruf et al., 2024).

**Carbohydrates**

The results of diversity analysis showed that the difference in levels had a very real different influence ($P<0.01$) on carbohydrate content. The BNJ test shows that the 20% level has a very real carbohydrate content ($P<0.01$) higher

than the 10%, 30% and 40% levels, as well as the 40% level has a very real carbohydrate content (P<0.01) higher than the 10% level and the 30% level (Table 1).

Carbohydrates are one of the important components in food products that function as the main source of energy for the body (Fitri & Fitriana, 2020). The use of starch in meat products also helps to stabilize emulsions and gels, improving their rheological behavior. The network formed by interactions between myofibrillar, sarcoplasmic, stromal proteins, fats and starch contributes to the structuring of emulsions, with positive effects on the yields in finished products (Ianiţchi et al., 2023). In processed meat products such as nuggets, the carbohydrate content mostly comes from fillers that can reduce the cost of the main ingredient, namely meat (Abubakar et al., 2011). This study uses Provit A1 corn flour as a filler, which is not only rich in beta-carotene, but also has a significant carbohydrate content. Variations in the concentration of Provit A1 cornmeal (10%, 20%, 30%, and 40%) affect the total carbohydrate content in duck nuggets.

The carbohydrates in the nuggets increased along with the increase in the concentration of corn flour in Provit A1. At a concentration of 10%, Provit A1 cornstarch contributed to a moderate increase in carbohydrates in nuggets. With a substitution of 20%, the total carbohydrates in the nuggets increased more significantly, reaching 12-15%. This concentration provides a good balance between the protein from the duck meat and the carbohydrates from the filling, resulting in a chewier and more stable nugget texture. The increase in juiciness and tenderness of meat products in whose composition vegetable derivatives were introduced was also reported by Ianiţchi et al. (2023). At a concentration of 30%, the carbohydrate content in the nuggets is estimated to increase by 18-22%. Nuggets at this concentration have a denser texture due to increased starch levels, which serve as a natural binder in the nugget batter. A substitution of 40% yields the highest carbohydrate content, which is around 25-30%. According to Wellyalina and Aisman (2013), the quality of nuggets is influenced by the amount or concentration of filler ingredients added.

**Cholesterol**

The results of the diversity analysis showed that the difference in levels had a very significant different influence (P<0.01) on cholesterol content. The BNJ test showed that the 20% level had a very real cholesterol content (P<0.01) higher than the 10%, 30% and 40% levels, as well as the 30% level had a very real cholesterol content (P<0.01) higher than the 10% level and the 40% level.

Cholesterol is a lipid compound that is naturally found in animal foods, especially meat, eggs, and processed meat-based products such as nuggets (Rahmat and Wiradimadja, 2011). The cholesterol content in nuggets is influenced by the base ingredient (duck meat) and additives such as fillers (Nurhayati et al., 2024).

Provit A1 cornmeal, which is a plant-based ingredient, does not contain cholesterol, so its substitutions with concentrations of 10%, 20%, 30%, and 40% can contribute to lowering overall cholesterol levels in nugget products.

Duck meat is known to be rich in protein, but it has higher levels of fat and cholesterol than other poultry such as chicken. Research results from Sukada et al. (2007) and Sjofjan and Djunaidi, (2016) showed that as much as 100 g of duck meat has a higher cholesterol of 80 mg/dl compared to chicken cholesterol of 60 mg/dl. However, in processed products such as nuggets, cholesterol levels can be affected by the additives used. Since Provit A1 cornmeal does not contain cholesterol, its use as a filler serves to reduce the percentage of total cholesterol in the nugget product. At a concentration of 10%, cornstarch replaces a small portion of the meat ingredient in the nugget formulation. The cholesterol content is estimated to decrease by about 5-7% compared to the control (without Provit A1 cornmeal), with a total cholesterol level of about 65-75 mg per 100 grams. With a substitution of 20%, cholesterol levels are reduced more significantly, which is around 10-15%. In this treatment, the cholesterol in the nuggets is estimated to reach 60-70 mg per 100 grams, as cornstarch replaces more meat parts in the formulation. A substitution of 30% resulted in a reduction in cholesterol by up to 20-25% compared to control. The cholesterol content in nuggets at this concentration is estimated to

range from 55-65 mg per 100 grams, making it more friendly for consumers who need low-cholesterol products. Reducing the concentration of fat and cholesterol in meat products is advantageous, as high consumption of fatty and processed meats is associated with an increased risk of cardiovascular disease or type 2 diabetes (Ianiţchi et al., 2024).

The substitution of Provit A1 cornmeal in duck nuggets effectively reduces the total cholesterol content in the product. A concentration of 30-40% Corn Flour Provit A1 provides a significant reduction in cholesterol without sacrificing the quality of the product's texture and taste. This nugget is suitable for consumers who want to enjoy processed meat with lower cholesterol levels.

**Microstructure by Electromagnetic Scanning method (SEM)**

Provit corn starch granules A1 level 10% tend to be round or oval. The surface of the granules looks smooth and regular. Granules can vary by about 5-20 micrometers (Figure 1).

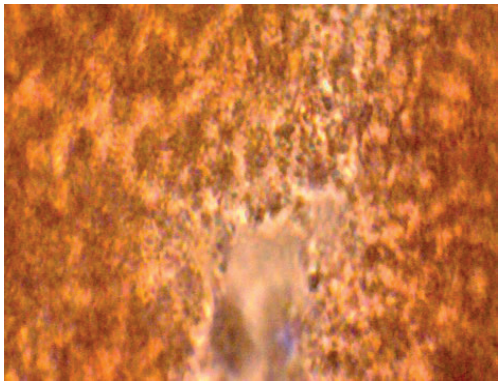

Figure 1. Microstructure of Afkir Duck Nuggets using Proviot A1 (10%) Corn Flour as Filler

The size distribution can be seen, with some granules larger or smaller than others.

According to Huff Lonergan and Lonergan (2005), that granules depend on amylose and amylopectin through strong, abundant and regular intermolecular hydrogen bonds forming crystalline regions and otherwise will produce amorphous regions. The surface of the granules shows a smooth texture can look slightly porous, which can affect the rheological properties and interactions with other materials (Chen et al., 2018). At the 10% level, there is a slight agglomeration of the granules, depending on the processing or storage method used. If there is an aggregate, this can affect the flow properties and dispersibility of starch. Observation of the granules with polarization microscopy showed a birefringence cross that appeared to be the intersection of two bands (Maltese cross), indicating a radial arrangement of amylose amylopectin forming a semi-crystalline character. The structure of the granules depends on the interaction of amylose and amylopectin through intermolecular hydrogen bonds. Strong, numerous and regular interactions form crystalline regions and if otherwise will produce amorphous regions (Huff Lonergan and Lonergan, 2005).

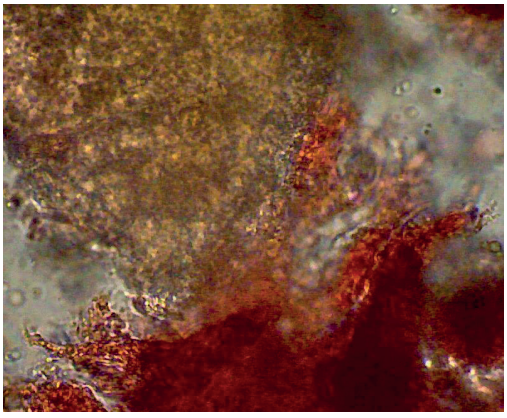

Figure 2. Microstructure of Afkir Duck Nuggets using Proviot A1 (20%) Corn Flour as Filler

Results of SEM reading of corn starch 20% granule morphology

Corn starch granules are generally round or oval in shape (Figure 2). At a concentration of 20% the granules showed variation in shape, with some granules being more irregular due to interactions with other materials. The particle size at this concentration usually ranges from 10-30 micrometers. The size distribution can indicate the presence of variation, where some granules may be larger or smaller than average. The surface of corn starch granules at a concentration of 20% tends to be smooth, but may exhibit some pores or a coarser texture compared to lower concentrations. Alcázar-Alay and Meireles et al. (2015) stated that the existence of this texture can affect the rheological properties and the ability of

granules to be dispersed in other media. At a concentration of 20%, there is a possibility of granule aggregation, where multiple granules may stick together. When compared to starch granules at the level of 30%, granules at the level of 40% look more dense and compact.

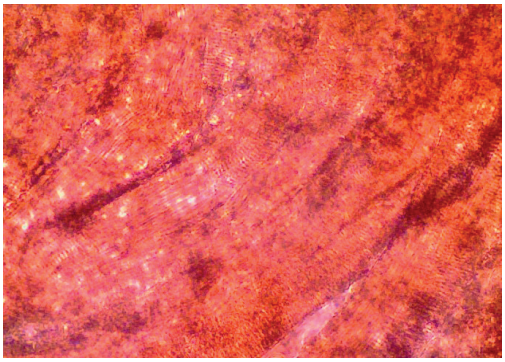

Figure 3. Microstructure of Afkir Duck Nuggets using Proviot A1 (30%) Corn Flour as Filler

Granule shape: at the level of 30% it usually remains round or oval (Figure 3). However, at higher concentrations, the shape may become slightly irregular or more complex, as a result of the higher interaction between the granules. The size of the granules at this concentration usually ranges from 15-35 micrometers. There is a possible more pronounced variation in size compared to lower concentrations, with some of the larger granules due to clumping. The Distance between granules can vary and depends on the level of aggregation. Some granules may stick together, reducing the space between them, while others remain more spaced. The morphology of starch granules is almost the same, where each starch granule forms an irregular polygonal structure that is swollen and unevenly distributed (Chen et al., 2018).

Birefringence itself is formed due to the difference in light refraction patterns from crystalline and amorphous regions (Czukor et al., 2001). Birefringence is the ability to double the refraction of polarized light. The whole starch granule in its natural form shows birefringence comparable to its crystal structure. The birefringence pattern in starch granules represents the radial arrangement of amylopectin molecules, and their branching chains form a 90° angle with the tip reduced towards the hilum or center of the starch granules (Alcázar-Alay and Meireles, 2015).

A high concentration of Provit A1 corn (40%) produces nuggets with a microstructure dominated by fillers (Figure 4). The protein matrix is significantly damaged and is unable to cover the filler optimally, resulting in a very hollow and less compact texture. Nuggets tend to be brittle, with greatly reduced water holding capacity. At this concentration, the effect of Provit A1 corn on microstructure and texture showed poor results for product quality.

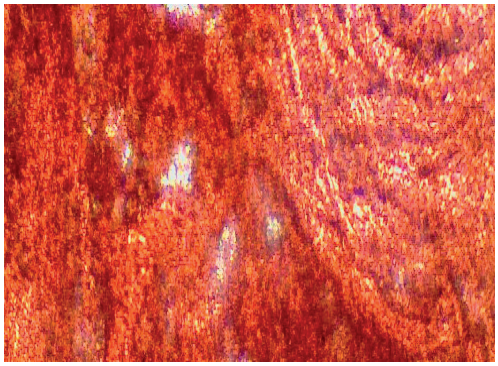

Figure 4. Microstructure of Afkir Duck Nuggets using Proviot A1 (40%) Corn Flour as Filler

## CONCLUSIONS

Nuggets with a concentration of 20-30% Provit A1 cornmeal provide the best balance between beta-carotene content, a concentration of 20% provides a good balance between protein from duck meat and carbohydrates from fillers, while a concentration of 30-40% Provit A1 cornstarch provides a significant reduction in cholesterol.

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