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In Vitro Starch Digestibility and Total Carotenoid of Corn from Various Type of Processing

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A B S T R A C T

This research aims to study in vitro starch digestibility, total carotenoid, and nutritional content from various types of corn processing. The design used in this study was explorative with six treatments: raw, boiled, steamed, roasted, fried, and puffing. The results showed that the lowest water content was found in popcorn (0.93%), the lowest ash content in raw corn (0.52%), the lowest fat content in raw corn (0.61%), the highest protein content in raw corn (8.80%), the highest starch content in popcorn (59.19%), the lowest amylose content in fried corn (19.56%) and the highest amylopectin in fried corn (80.44%), FFA content (0.33%) in fried corn, the highest carotenoid content (11.05 µg/g) was found in raw corn and the lowest carotene content(6.01 µg/g) was found in popcorn, the lowest starch digestibility (47.36%) was found in raw corn

1. INTRODUCTION

1.1. Research Background

Corn (*Zea mays*, L) is one of the crops that contains chemical components of carbohydrate (63.6 g), protein (7.9 g), fat (3.4g), Ca (9 mg), P (148 mg), Fe (2.1 mg), Vitamin A (440SI), Vitamin B1 (0.33 mg) Water (24g) and energy (307 kcal) in 100 g of yellow corn [1].

According to Ref. [2], the processing generally affect the digestibility, nutritional content, total carotenoids, appearance, flavor. Cooking practice by involving heat is one of the food processing, processes that are mostly done in household or industrial scale. Besides that, according to Ref. [3] cooking process causing the gelatinization of starch by the process of the breakup of granular starch is a molecule of starch to be more easily digested. Corn can be the product of corn processed which is steamed corn, corn grilled, fried corn and popcorn that until the time is yet no information about the quality of nutrition, total carotenoid and the digestibility. Based on the description above then need to do the testing on the digestibility, total carotenoids and content of nutrients generated from some of the products processed corn.

1.2. Literature Review

Boiling is a processing process using boiling water around 100 °C, where the water is used as a medium for conducting heat [4]. The treatment process using water for a long time can cause an increase in digestibility [5].

Roasting of food can be done by burning directly over the fire or by using the oven. Processing that uses dry heat methods such as burning, which causes the carbohydrates to break down and form a dark colour (Mailard reaction) [5].

According to Ref. [6], frying is a food processing process that can reduce nutritional content by using temperatures of more than 160 °C, so that protein is damaged because the higher the temperature is used, it can cause protein levels in food to decrease. Ref. [7] states that puffing is one of the food processing processes in which the food material can experience volume expansion or expansion due to the influence of temperature and pressure treatments, resulting in a change in the structure of the. One of the puffing material products is in the form of breakfast cereal or ready to eat cereal. Popular products are puffed corn or popcorn.

1.3. Research Objective

This research aimed to study in vitro starch digestibility, total carotenoid, and nutritional content from various types of corn processing.

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2. MATERIALS AND METHODS

2.1. Material and Equipment

Materials used in this research corn hybrid NK 22 consisting of corn young corn and old corn from farmers in West Sumatra. Chemical Materials which was used is H_2SO_4, CH_3COOH, alcohol 96%, KOH 0.1N, distilled water, aluminum foil, paper filter, NaOH, HCl 3%, NaCl, NaOH 4 N, solution of Luff schoorl, KIO_3, $Na_2S_2O_3$ 0.1 N and 0.5%of starch solution, amylose, ethanol 95%, an iodine solution, Na-phosphate buffer, hexane, phenolphthalein, selenium mix, αamylase enzyme solution, dinitrosalicylic acid solution, Na_2CO_3 and methyl orange indicator .

The tools used are pans, knives, basins, grills, stoves, pans, ovens, porcelain cups, furnaces, analytical scales, soxhlets, desiccators, Kjeltec analysis, 500 ml erlenmeyer, 250 ml measuring flask, drop pipette, water bath , test tubes spectrophotometer, vortex.

2.2. Research Design

The design used in this study was exploratory with six processing methods and three replications. The processing treatments used are as follows: Control (without treatment), Boiled Corn, Steamed Corn, Roasted Corn, Fried Corn, Pop Corn.

2.3. Research Implementation

2.3.1. Boiled Corn

The stage of making boiled corn: (1) 1 l of water is boiled (100 ^oC) in a pan ± 10 minutes, (2) Put 250 g of corn into the pan when the water boils (100 ^oC) for ± 30 minutes; (3) Boiled corn is lifted and drained; (4) The products are ready to be analysed.

2.3.2. Steamed Corn

The stages of making steamed corn: (1) 1 l of water is boiled (100 o C) in a steaming pot ± 10 minutes; (2) Put 250 g of corn into the steaming pan when the water boils (100 ^oC) for ± 30 minutes; (3) Steamed corn is lifted and drained; (4) The products are ready to be analyzed.

2.3.3. Roasted Corn [1]

The stages of making roasted corn: (1) Corn weighed 250 g;(2) Corn is burned with coconut shell charcoal (180-270 ^oC) ± 15 minutes and turned over if it has a uniform roasting; (3) Roasted corn is ready to be analysed.

2.3.4. Fried Corn [8]

The stages of making fried corn: (1) Corn grain as much as 500 g soaked for 3 hours and then drained; (2) Boiled (100 ^oC) for 2 hours until corn is tender and chapped, then removed and drained; (3) Corn grain is dried for 2 days under the sun or until the corn grain water content of about 16%; (4) Corn grain fried at a temperature of 160-205 ^oC until the colour of yellow -brown for ± 5 minutes; (5) Then drained; (6) Fried corn grain is ready to be analysed.

2.3.5. Pop Corn [8]

The stage of making popcorn with puffing techniques: (1) Heated 5 g margarine until melted; (2) 10 grams of grain corn (13.5-14% moisture content) is put into a closed pot (200-215 ^oC) and the pan is shaken to make all corn seeds exposed to margarine; (3) Grain corn is left for ± 10 seconds until the corn expands or until the explosion sound is complete; (4) Pop corn is ready to be analysed.

2.4. Observations

The observations aimed to compare the value of nutrition between before processing raw corncob without treatment and after treatment: Boil corn, steamed corn, roasted corn, fried corn and popcorn . Chemical observations consisting of water content, ash content, fat content, protein content, starch content, amylose and amylopectin content, total carotenoid. The nature of the functional form: power digestibility of starch in vitro, made a comparison between raw corn, boil corn , steamed corn, roasted corn, fried corn and pop corn

3. RESULT AND DISCUSSION

3.1. Moisture Content

Corn moisture content from several treatments can be seen in Table 1.

Table 1. Corn Moisture Content from Several Treatment

Treatment	Moisture Content (%)
Control	50.54 ± 0.70
Boiled corn	50.35 ± 5.79
Steamed Corn	60.24 ± 2.44
Roasted corn	50.77 ± 1.99
Fried Corn	3.52 ± 0.63
Pop Corn	0.93 ± 0.41

The water content of control and five corn processing ranged from 0.93 to 60.24%. The control water content obtained was 50.54% The water content lower if compared to the list of corn chemical composition by Ref. [9] which was 72.20 %. This difference is influenced by the variety and place of corn grow. Water content of food stuffs in the process of boiling, baking, frying and puffing has decreased than a control. This is because the boiling process using a temperature of 90-100^oC, roasting using temperature 180-270^oC, fryers use a temperature of 160-205^oC while Puffing use temperatures of about 200- 215^oC. Processing of material food by using a high temperature can causing the evaporation of water on the material of food such. The higher temperature, will lower the levels of water [6].

3.2. Ash Content

Ash content of corn from several treatments can be seen in Table 2.

Table 2. Corn Ash from Various Processing Type

Treatment	Ash content (%)
Control	0.52 ± 0.12
Boiled corn	0.73 ± 0.11
Steamed Corn	0.73 ± 0.23
Roasted corn	0.99 ± 0.21
Fried Corn	1.20 ± 0.20
Pop Corn	1.33 ± 0.11

Ash content and five corn processing ranges from 0.52 to 1.33%. The highest ash Content is found in processing corn in fried corn and popcorn , while processing popcorn products using margarine Presence of sodium in margarine led to an increase in the levels of ash that sodium is one of the minerals were included of the salt main [10] In addition the mineral content of old corn is higher compared to young corn based on the list of corn chemical composition by Ref. [11] namely yellow corn has 10 mg of calcium, 256 mg of phosphorus, 2.4 mg of iron while young corn of calcium 7 mg, phosphorus 100 mg, and 0.5 mg iron. High and low value levels of ash in food also depend on the temperature of the frying pan, the higher the temperature the more a lot of water content are missing [6].

3.3. Fat Content

Corn fat content from several treatments can be seen in Table 3.

Table 3. Corn Fat Content from Various Processing Type

Treatment	Fat content (%)
Control	0.61 ± 0.04
Boiled corn	0.68 ± 0.17
Steamed Corn	0.92 ± 0.10
Roasted corn	1.82 ± 0.03
Fried Corn	15.09 ± 2.31
Pop Corn	29.18 ± 3.57

The content of control corn fat and five corn processing ranged from 0.61— 29.18%. The lowest fat content found in the control that is as much as 0.61% and the highest are in the processing of popcorn. In frying process causes the fat content material of food experienced a rise caused by an oil in addition to functioning as a medium conductor of heat the oil also will participate absorbed on the substance of food that the resulting fat levels experienced a rise [6]. In the puffing process, margarine used 1: 2 with corn is used so that it causes an increase of fat content in the product.

3.4. Protein Content

Corn protein content from several treatments can be seen in Table 4.

Table 4. Corn Protein from Various Processing Type

Treatment	Protein content (%)
Control	8.80 ± 0.05
Boiled corn	8.47 ± 0.11
Steamed Corn	8.66 ± 0.13
Roasted corn	6.33 ± 0.19
Fried Corn	7.85 ± 0.52
Pop Corn	7.18 ± 0.58

Protein content of control corn and five corn processing ranged from 6.33 to 8.80%. The highest of protein content in control is of 8.80% a little higher if compared with the composition of the chemical corn. According to Ref. [12] is as much as 8.40%. In the processing of corn into corn fritters and popcorn ,levels of the protein is lower than the control, while the water levels and the levels of protein popcorn obtained are equally low, it is caused due to the temperature of the frying pan using a temperature of 160-205 ºC and Puffing using a temperature of about 200 - 215 º C which causes protein levels to experience a decline, in addition to the level of maturity of the corn is different where the protein content of corn parents more higher than corn light based on the composition of the list of chemical corn by Ref. [11] corn yellow have levels of protein 9 2 g. According to Ref. [6] the higher temperature used causes the level of protein in food decrease.

3.5. Starch Content

The levels of corn starch from several treatments can be seen in Table 5.

Table 5. Corn Starch Content from Various Processing Type

Treatment	Starch content (%)
Control	39.53 ± 1.41
Boiled corn	30.75 ± 1.24
Steamed corn	26.70 ± 3.40
Roasted corn	36.49 ± 0.22
Fried Corn	50.35 ± 0.93
Pop Corn	59.19 ± 1.79

The content of control starch and five corn processing ranged from 26.70-59.19%. The content of starch in the control that is as much as 39.53 % case is much different when compared with the literature where according to Ref. [13] corn containing starch 54.1 to 1.7%. Difference is suspected because samples tested up to first do the drying and the results obtained are converted into wet besides, there are also differences in place of plants grow. Carbohydrates in corn mostly large a component of starch.

In the process of processing the corn by means boiled and steamed experienced a decrease in the levels of starch is more substantial than corn fuel, it is caused because of the content of starch is soluble in hot water. According to Ref. [14] starch does not dissolve in cold water but dissolves in hot water, starch granules become soluble. While in the process of processing fried corn experienced a significant decrease compared to popcorn for the processing glorious fried previously done thus causing the decrease in the levels of starch.

Different ways of processing can have an influence on the starch content of processed products. This is supported by research conducted by Ref. [15] which reveals the increasingly high temperatures that given the levels of starch is getting low, because temperature affects the rate of decay granules that cause damage to the molecules making up the starch so that the number of molecules of starch will form new bonds that are not strong (not easily dissolved) less and less.

3.6. Amylose and Amylopectin Content

Corn amylose and amylopectin levels from several treatments can be seen in Tables 6 and 7. Amylose control content and five maize processing ranged from 19.56 - 27.31 %. The content of amylose highs are in control that is as much as 27.31 % is higher than corn normal when compared with literature according to Ref. [16] namely corn normally contains 15.3 to 25.1% amylose corn kind of waxy almost non amylose, amylomised corn contains 42.6 - 67.8% amylose and sweet corn contains 22.8 % amylose. However, it is lower when compared to the amylose content according to Ref. [17] namely

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in some varieties around 28.50 to 34.55%. This difference is influenced by the variety and place to grow plants.

Table 6. Corn Amylose Content of Various Processing Type

Treatment	Amylose content (%) ±DS
Control	27.31 ± 0.80
Boiled corn	21.81 ± 0.70
steamed corn	20.03 ± 1.50
Roasted corn	24.07 ± 3.15
Fried Corn	19.56 ± 1.89
Pop Corn	23.35 ± 1.15

Decrease in amylose content caused by an increase in temperature resulting in amylose constituent component of starch decrease. Increased starch solubility due to heating of starch suspense is higher due to amylose has undergone depolymerization. The higher temperatures causes the depolymerization of molecules of starch [18]. Amylose is a starch component that has straight chains and dissolves in water [19].

Table 7. Corn Amylopectin Content from Several Processing

Treatment	Amylopectin levels (%) ± DS
Control	72.69 ± 0.80
Boiled corn	78.19 ± 0.70
Steamed corn	79.97 ± 1.50
Roasted corn	75.93 ± 3.15
Fried Corn	80.44 ± 1.89
Popcorn	76.65 ± 1.15

The amylopectin content of the control and five maize processing ranged from 72.69 to 80.44%The content of amylopectin in the control that is as much as 72.69 % and corn have included types of maize normally. Maize can be classified into four types based on the nature of the starch, namely the normal type contains 74-76% amylopectin and 24-26% amylose, the waxy type contains 99% amylopectin, amilomaize contains 20% amylopectin or 40 to 70 % amylose and sweet corn contains a certain amount of sucrose besides starch [13].

The composition of amylose and amylopectin affects the sensory taste of corn, especially the texture and taste. The higher the amylopectin content, the softer the texture, the fluffier and the better the corn taste. The composition also affects the nature of the amilograph [20].

3.7 In *vitro* digestibility of starch

The in vitro digestibility of corn starch from several treatments can be seen in Table 8.

Table 8. In Vitro Digestibility of Starch Corn

Treatment	Starch Digestibility *In Vitro* (%)
Control	47.36 ± 2.59
Boiled corn	64.14 ± 2.19
Steamed corn	65.42 ± 0.95
Roasted corn	49.79 ± 0.71
Fried Corn	79.92 ± 5.32
Pop Corn	58.96 ± 1.00

The content of the power digestibility of starch control and five processing of corn ranged between 47.36 to 79.92%. The content of the power digestibility of starch lows are in control that is as much as 47.36% is lower when compared with according to Ref. [21] the digestibility of starch flour corn that is as much as 57.04%. The content of the power digestibility of starch highest that is contained in the processing of corn into corn fritters as much as 79.92%. Because the processing of corn fritters before done boiling so as to increase the power digest. According to Ref. [5], processing with water in a long time causes an increase in power digest. The cooking or processing of food causes the difference in the level of digestibility of starch. The starch gelatinization process causes changes in amylose structure that were initially crystallized to amorphous, thus increasing the digestibility of starch [22]

Factors affecting the digestibility of starch are levels of amylose. The results obtained are in accordance with the literature where the higher the amylose content obtained , the lower the digestibility of starch. This is supported by Ref. [23] which states that the amylose content is one of the factors that can affect the digestibility of starch. The content of amylose is higher cause digestion becomes more slowly because amylose is a polymer of glucose that has a structure not branched (structure more crystals by bonding hydrogen more extensively). Amylose also has bonding hydrogen is more robust than with amylopectin, so it is more difficult to be hydrolysed by the enzyme digestion [24] Structures that are not branched is made of amylose bound to be strong so difficult and consequently difficult to digest [3]. Another factor affecting the power digestibility of starch that is where anti nutrition, antiamilase (fiber food and tannin, structure chemistry starch (starch resistant).

3.7. Total Caratenoid

Total corn carotenoid from several treatments can be seen in Table 9.

Table 9. Total Corn Carotene from Various Processing Types

Treatment	Total Carotenoid (µg / g) ± SD
Control	11.05 ± 0.36
Boiled corn	8.71 ± 0.33
Steamed Corn	8.55 ± 2.35
Roasted corn	8.12 ± 0.28
Fried Corn	6.46 ± 2.49
Pop Corn	6.01 ± 1.21

The control carotenoid content and five maize processing ranged from 6.01-11.05 µg/ g. The content of carotenoids highs are in control that is as much as 11.05 g/g case is not much different when compared with the characteristics typical corn colored yellow because the content Carotenoid and Carotenoid in the corn ranged from 6.4 to 11.3 ug / g of which 22% is beta carotenoid and the rest is xanthophyll. Both the conten t of carotenoids that have a role that is quite important. Beta carotenoid as a pro vitamin A which plays a role in preventing blindness caused by cataracts. Xantofil role as protector of cells from attack cancer, as an antioxidant, as a system of immunity of the body and prevent diseases of the heart [25].

The higher the temperatures and the longer the cooking process, the total carotenoid corn will decline. The decrease in

total carotenoid is due to the processing of corn using heat. According to Ref. [26] the content of carotene will decrease in line with the increasing temperature and duration of cooking. It is caused due to carotene degraded due to the oxidation process at a temperature high which causes the structure carotene is not stable.

Beta carotenoid normally consumed by the human body is 3-6 mg per day [27]. The results showed that 1g of corn contained beta carotenoid, so to meet the needs of 3 mg of beta carotenoid one day was equivalent to consuming control of 272 g, boiled corn 344 g, steamed corn 351 g, roasted corn 369 g, fried corn 464 g, and pop corn 499 g.

4. CONCLUSION

The results showed that corn processing which had the lowest water content was found in processing corn into popcorn that was 0.93%, the lowest ash content in the control was 0.52%, the lowest fat content in the control was 0.61%, the highest protein content in control is 8.80%, the highest starch content in popcorn is 59.19%, the lowest amylose content in fried corn is 19.56%, the highest amylopectin content in fried corn is 80.44%, the lowest total digestibility of starch in control which is 47.36%, the highest total carotene in the control is 11.05 µg/g and the lowest total carotene in popcorn is 6.01 µg / g. Based on this research, the authors suggest to researchers further in order to carry out the assessment is more about the value of the glycemic index of some processing of corn as a reference in determining the amount and type of food source of carbohydrate that is appropriate to improve and maintain health.

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