International Journal of Scientific Research and Management (IJSRM)
||Volume||10||Issue||2||Pages||ND-2022-43-63||2022||
Website: www.ijsrm.in ISSN (e): 2321-3418
DOI: 10.18535/ijsrm/v10i2.nd02

Preparation and quality evaluation of flour and biscuits made from red corn powder using as supplement with different ratios of red corn flour

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Abstract
The consumption of cereal foods such as biscuits has become very popular globally. Also, in recent years, nutritional potential is prioritized in every foodstuff. Different types of maize such as yellow, sweet corn are one of well-known healthy ingredients for developing new biscuit products, except red corn. This has spurred pragmatic research on developing biscuits prepared by blending wheat flour with red corn powder in ratios of 5%, 10%, and 15%. This study was, conducted to investigate functional properties of composite flours. The effects of three levels of red corn powder in the physical dimensions, nutritional constituents, consumers' acceptability and compared to the quality of 100% wheat biscuits. In essence, partial substitution of wheat flour with red corn powder witnessed an increase in protein and fiber. Besides, a significant increase was noticed in total phenolic content and the antioxidant ($p<0.05$) compared to control samples. 5% and 10% red corn flour-biscuits also predominated the most in the sensorial acceptability. The collected results of this study witnessed an improvement in terms of nutritional value, health benefits and a high potential of being accepted by consumers of developed biscuits.

Key words: red corn powder, Biscuits, Nutritional value, Antioxidant, Total phenolic content, Fiber content, red corn supplemented biscuits.

Introduction

Corn is also known as maize (Zea mays). Corn is religiously a significant food source all over the world that contains a vast number of bio-active compounds supplying different desirable health benefits beyond its role. Moreover, corn grain, sweet corn is considered as one of the most famous vegetables in North America and China, as well as its mainstream has been spreading in the world. To illustrate, sweet corn is one of the kinds of vegetables among the top six that is most consumed in the United States. Beside that canned and frozen sweet corn is also ranked the third place in the same country which only went after canned tomatoes and frozen potatoes (Siyuan, S., Tong, L., & Liu, R. H., 2018) [1]. In Viet Nam, maize is the second most important food crop after rice. It is widely grown throughout the country from plains to midlands and especially in the mountains. There are many types of maize, often classified into different types in terms of properties and uses such as sticky corn (white seeds, flexible grains), mainly for eating, ordinary corn (white or yellow seeds). High amounts should be used as animal feed. Two types are corn sugar (irregular yellow grain), sweetness and vegetable corn (small corn, low starch) for eating.

Red corn which is known in Viet Nam as "Nu Hoang Do" is one of a type of sweet corn. It is claimed that it is important to harvest it at the proper stage of maturity. The red color in red corn is created by the plant pigment, anthocyanin. The red gene is recessive; thus, a high percentage of red kernels must be planted to maintain the color variation (Red corn, n.d.) [2]. In contrast to genetically modified products, red corn in Viet Nam is an F1 corn variety that has been bred according to the traditional breeding method. The red-violet pigment of its corn is known as Anthocyanin which is an organic compound with antioxidant and antibacterial activity that red corn has the effect of regulating blood pressure, preventing cancer and reducing inflammation swelling (Giang, 2019) [3].

It is well-recognized that the benefit of corn and some whole grain is contributed by some macro nutrients such as carbohydrates, vitamins, and minerals. It is also from their unique phytochemicals such as phenolic acids. The consumption of corn and other whole grain products has been connected to the declined the risk of chronic diseases including cardiovascular disease, type 2 diabetes, obesity, some cancers and with the improvement of digestive tract health (Siyuan, S., Tong, L., & Liu, R. H., 2018) [1]. The production of red corn is not widely known all over the world while it has a variety of ways to consume. Red corn can be used in place of white and yellow sweet corn, though it does mature more quickly and can tend to contain more starch than yellow and white varieties. Red corn can be hulled fresh for salads and soups. It can be ground into flour for corn breads, flat bread, pancakes, tortillas, and it is traditionally used in stews and hominy (Red corn, n.d.) [2].

Biscuit has been one of the oldest baked goods and consumed extensively all over the world by all age groups. The popularity of biscuits comes from their attributes such as high palatable, dense nutrients, quickly released energy and available in convenient sizes as well as in various forms. In addition, the biscuits formulation can be modified easily to meet the nutritional demands of the target consumers (Ashaye, Olanipekun et al. 2015) [4]. Since biscuits are dried to low moisture content, this ensures their long storage shelf life and free from microbial spoilage (Okaka 2005) [5]. The bakery industry is growing rapidly, and the products are becoming increasingly popular with consumers around the world. Among ready-to-eat snacks, biscuits have many attractive characteristics including a wider consumption base, a long shelf life and preferred eating standard. Although biscuits are a common food that is eaten by children as well as adults, they are usually high in the materials (fat and sugar) that make them unhealthy. In the manufacture, biscuits dough normally uses semi-solid fat at room temperature, e.g: palm oil containing 50 percent of saturated fatty acids. The biscuit market is also dominated by short dough biscuits with a fat content approaching 20%. Therefore, biscuits are an easy choice when customers are asked to reduce their total fat intake.

It is highly beneficial to create an appealing commercially available biscuit for children and adults with a substantial reduction in fat and sugar, with less calories and nutrients intended to minimize the risk of coronary heart disease (Boobier, 2006) [6]. Partial replacements or supplement of wheat flour with other nutritional ingredients to produce functional bakery products are highly recommended (Ihab S. Ashoush, 2016) [7]. Moreover, global consumers are looking for healthy food and products. Among many other greens and other types of corn, red corn is one of an unusual type that is not quite common worldwide but supplies us enough and more nutrient and energy than another one. There is a lack of scientific research on red corn as well as improving the flour and making biscuits from red corn flour. Therefore, it is scientifically and economically important to know whether the made flour red corn can be used to produce high-quality biscuits with enhanced and developed nutrition values. Also, a consequence of a variety of proportions of red corn to wheat flour in biscuits products.

In summary, this study has been conducted to determine the suitable process for preparation and possibly improved quality production of flour and the made biscuits from the red corn. It is well-known that Viet Nam is a tropical country which is very suitable for growing a variety of fruits and vegetables. Yellow and white corn is popular, however except for red corn ("Nu Hoang Do") which is very new to consumers in Viet Nam. It has higher nutritional value than normal ones and it also helps reduce many diseases such as diabetes, and controls blood pressure. It is still very little studied by scientists in biscuits processing. Consequently, the new biscuit with red corn is the main ingredient that could promote the richer nutritional bakery products to consumers. Beside that red corn replaces the wheat flour to improve the fiber, antioxidant substances and other nutrients contained in biscuits as well as increasing the utilization of indigenous crops cultivated in Viet Nam. Therefore, the aims of this study were to explore and determine the substitution of the wheat flour by red corn flour (gluten-free flours) in biscuits by trial baking samples in different ratios of both wheat flour and red corn flour and to develop the new recipe as well as determining the quality of biscuits.

Materials and Methods

Materials

20 fruits which is approximate 5 kilograms of red corn with good quality without any molds or insects were purchased from a local market in Ho Chi Minh City for vital ingredients.

There are other necessary ingredients to prepare biscuits such as typical wheat flour (type no.8) of Baker's choice brand, sugar, butter, eggs were obtained from Nhat Huong company, Ho Chi Minh City, Vietnam. High density polyethylene bags were used for package and storage of samples.
Chemicals applied in samples analysis include Ethanol, Hexane, Sulfuric Acid, Acid Boric, Sodium Hydroxide 96%, Gallic acid, Folin-Ciocalteu phenol reagent, 1,1-diphenyl-2-picrylhydrazyl (DPPH), Natri Carbonate and other tools that were purchased from local Chemical for laboratory agents in district 10, Vietnam.
The experimental studies were conducted in laboratories of the Department of Food technology, International University – Vietnam National University in Ho Chi Minh City.

Methods

Preparation of Red corn flour

Fresh red corn must be washed, split into individual seeds, and washed again to remove all undesired factors that could affect the final product. Before grinding, it must be dried at 40-45°C for 48 hours. The dried ones are grinded into smaller particles and then sieved through a standard sieve into 70 mesh size. The flour is then packed in an airtight container and stored at constant temperature for further use.

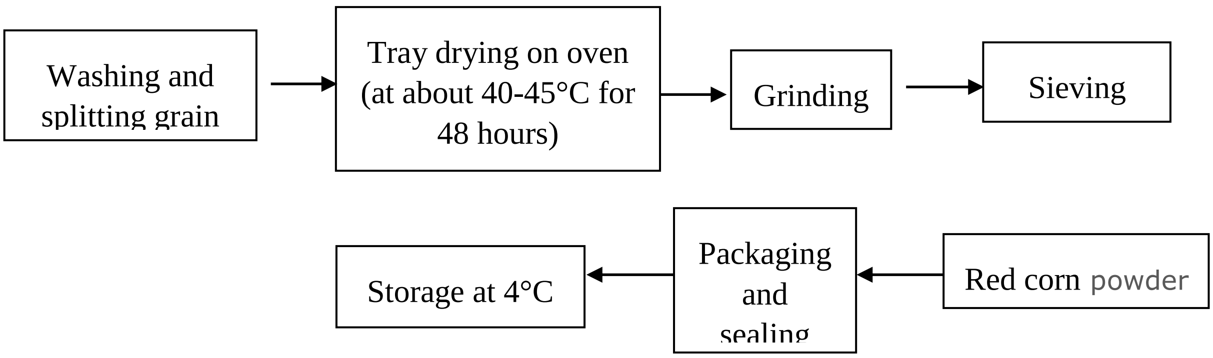

Figure 1. Red corn flour preparation flow chart

Production of Wheat-Red corn powder biscuits

Biscuits will be prepared by following the formula of table 1 which are: 200g wheat flour, 58g sugar, 63g butter, 1g salt and 1 egg. Incorporated biscuit samples were prepared by replacing 5%, 10%, and 15% of wheat flour. Therefore, the amounts of Wheat flour powder are proportional to red corn powder are 100:0; 95:5; 90:10; 85:15. Shortening and sugar were creamed in the mixer before the homogenized mixture of dried ingredients were added. Sieved flour was added to the cream and mixture for the next 2 minutes. The smooth dough was formed and sheeted to a 3-5mm of thickness. Then cut it using a circular mold to create a uniform shape for all biscuits and baked in preheated oven at 165°C for 15 minutes. After baking, biscuits were left to completely cool at room temperature and were wrapped tightly and kept until further analysis. As displayed in table 1, A is noticed as a symbol of control biscuits produced from 100% wheat flour. At the same time, B is marked biscuits produced from 95% wheat and 5% Red corn flour, C is marked biscuits produced from 90% wheat and 10% Red corn flour, D is marked biscuits produced from 85% wheat and 15% red corn flour

A = 100: 0 ratio of wheat - red corn flour in biscuits

B = 95: 5 ratio of wheat - red corn flour in biscuits

C = 90: 10 ratio of wheat - red corn flour in biscuits

D = 85: 15 ratio of wheat - red corn flour in biscuits

Table 1. The ingredients used in the preparation of red corn biscuits

No.	Ingredients (gram)	A	B	C	D

1	Wheat flour	200	190	180	170
2	Red corn flour	0	10	20	30
3	Sugar	58	58	58	58
4	Butter	63	63	63	63
5	Salt	1	1	1	1

Preparation of composite flour (wheat flour: Red corn flour) at different ratios (100:0, 95:5, 90:10, and 85:15)

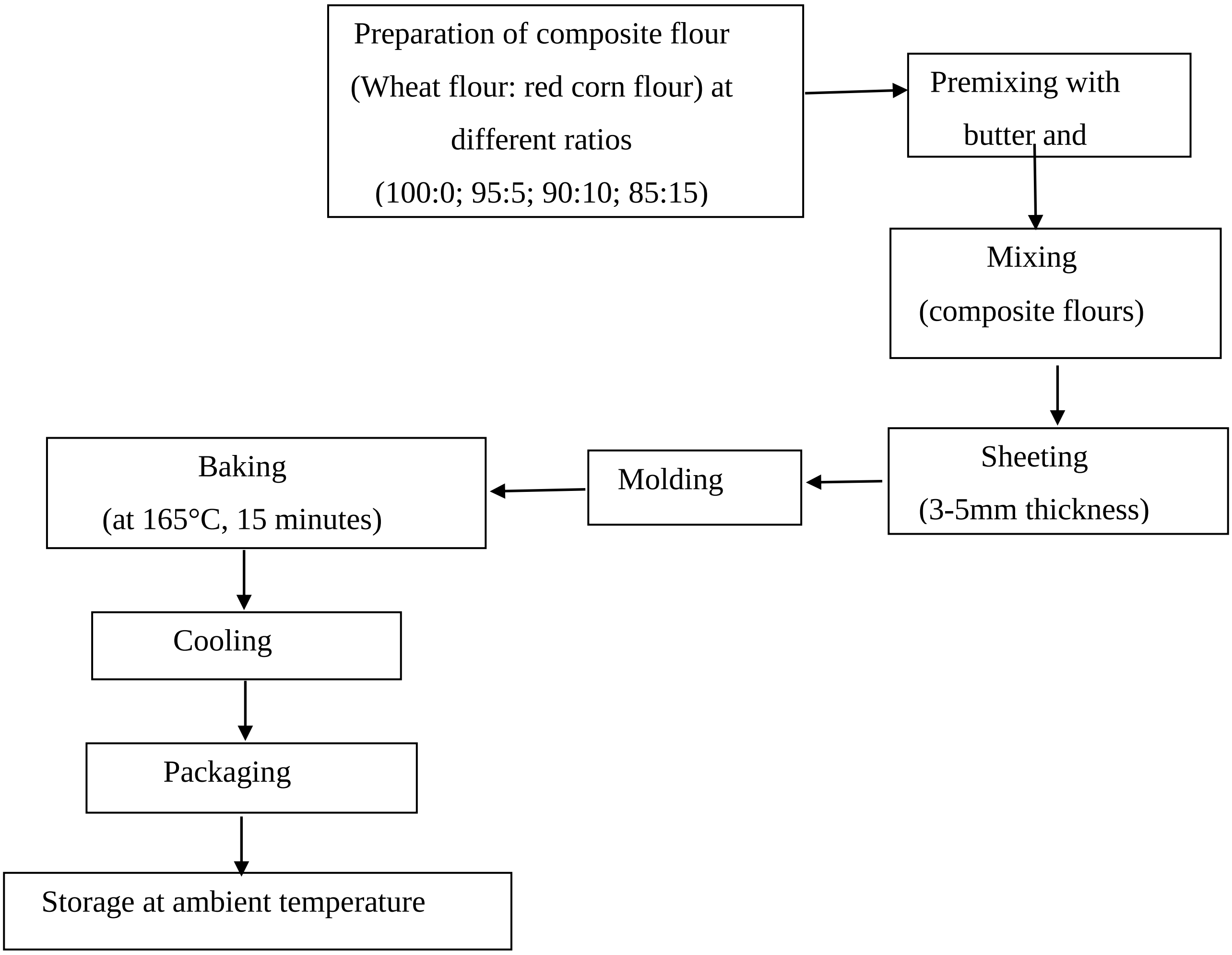

Figure 2. Flow chart for biscuits production

Proximate composition analysis of red corn flour and wheat flour
Red corn flour and different ratio composite flours were determined; the chemical compositions such as moisture content, protein, ash, crude fiber, fat content and energy value are determined by the methods described by A.O.A.C (2012), water absorption capacity, oil absorption capacity and bulk density. Total carbohydrate is calculated as the difference method.

Moisture content
The moisture content was determined with ground corn flour approached by a forced draft oven at 130°C

which had to weigh 2g of sample first in crucibles. After 30 minutes weight the crucibles until no change in weight is observed and record the final data.

Ash content

Ash content was determined by a muffle furnace at 550°C. Firstly all samples must be recorded with the moisture content by force draft oven at 130°C. The crucibles containing dry samples were re-weighed and primarily burn the content of materials by flame in a fume hood before placing them in a muffle furnace at 550°C for 3 hours and cool down for 2 hours in muffle furnace until it completely ashing which is turned white and free of carbon. The samples were then removed from the furnace and re-weigh immediately. The weight of ash (residue ash) was then calculated (AACC International 2010, St. Paul, MN) [8] as:

$$\%Ash(wb) = \frac{W2 - W1}{Weighofsample \times 100\%}$$

Where: W_1 = Weight of Empty crucible W_2 = Weight of crucible + Ash

$$\%Ash(db) = \frac{\%Ash(wb)}{(100\% - \%moisture) \times 100\%}$$

Protein content

Protein content of flour was determined by the Kjeldahl nitrogen procedure (Food Analysis Lab Manual, March 2017) [9]. 1g of sample was placed in a digestion tube, add 0.2g CuSO4, 1g K2SO4, and 20ml concentrated H2SO4 into the tube. The sample was let digested on digestion block until white fumes can be seen and continue heated for about 60 – 90 minutes until cleared with no charred material remaining. Tube was placed in the distillation apparatus and 50ml NaOH 32% was added. The ammonia in the sample was steam - distilled for 5 minutes into a receiving flash containing 4% boric acid. They were titrated with H2SO4 0.1N solution and protein content was calculated by

$$\%N = Normality\ H2SO4\ \times \frac{correctted\ acid\ vol.(ml)}{g\ of\ sample} \times \frac{14\ g\ N}{mol} \times 100$$

% Nitrogen multiplied with 6.25 (protein factor)

Fat content

2g of each sample is extracted with hexane using Soxhlet apparatus for 6 hours. The residual hexane was removed from the extracted sample by evaporation. The extracted fat was then dried in the oven overnight and weighed (AOAC, 2012).

$$fat\ (\%) = \frac{weight\ of\ sample\ after\ drying - weight\ of\ empty\ cup}{weight\ of\ sample\ taken} \times 100$$

Crude fiber

Crude fiber was determined following the approved AOAC method 962.09. Crude fiber is loss on ignition of dried residue remaining after digestion of sample with 1.25% H2SO4 and 1.25% NaOH solutions under specific conditions. 2g of each sample was extracted with ether or petroleum ether and transferred to beakers of ceramic fiber mixture. Two beakers of ceramic fiber mixture for each sample were prepared as follows: 1.5 g dry weight of sample was added to each 100 ml beaker, then 60-75 ml 0.255N H2SO4 was added to each beaker and allowed to soak. Beakers were placed on a digestion apparatus with pre-adjusted hot plates and boiled for exactly 30 minutes. Contents of beaker were filtered through Buchner funnel (pre-coated with ceramic fiber if extremely fine materials are being analyzed). Beaker was rinsed with 50-75 ml boiling H2O and washed through the Buchner funnel. Residue was removed before 200 ml 1.25% NaOH was added and boiled exactly 30 minutes. Contents were filtered and then washed with 25 ml boiling 1.25% H2SO4, 50 ml H2O and 25 ml alcohol. Residue was transferred to a washing dish, dried for 2 hours at 130 ± 2^{o}C. Then, it was cooled in a desiccator and weighed. Residue was ignited 30 minutes at 600 ± 15°C and cooled in desiccator before being reweighed.

% Crude fiber in ground sample = C = (Loss in weight on ignition loss in weight of ceramic fiber blank) x 100 - weight sample

Total carbohydrate content

Total carbohydrate content follows total carbohydrate (%, DW) = 100% - protein content (%, DW) – lipid content (%, DW) – ash (%, DW) *(Hung, P. V, 2012).*

Energy values

The total metabolizable energy is expressed in kilocalories (kcal / 100g), which was calculated by considering Atwater's conversion factors: (4 x g protein) + (4 x g carbohydrates [total carbohydrates – food fiber]) + (9 x g total lipids), as recommended by *(Osborne, D. R and Voogt, F., 1978)* [10].

Functional properties analysis of the composite flour samples

Bulk density

Bulk density was determined following the method described by *Eleazu and Ironua (2013)* [11] and AOAC, 2006. A (10ml) graduated cylinder, previously tarred, was gently filled with 5g of sample. The bottom of the cylinder was gently tapped on a laboratory bench several times until there was a constant. The bulk density of the sample (g/ml) was calculated as weight of the sample per unit volume of sample *(Nwosu, 2011)* [12].

Water Absorption Capacity (WAC)

Using the method as described by *Eleazu and Ironua (2013)* [11] *and the AOAC, 2006* with some modification, the WAC of samples were determined. Distilled water (10ml) is used to disperse 1g of samples in a conical graduated centrifuge tube. After mixing thoroughly in 30 seconds and standing at room temperature for 30 minutes. Next, they were centrifuged at 4000 rpm for another 20 minutes. The volume of the supernatant was measured directly from the graduated centrifuge tube. The amount of the absorbed water was multiplied by the density of water (1 g/ml) and results were expressed as g/100 g.

Oil Absorption Capacity (OAC)

Oil absorption capacity of the flour was determined using the method as described by *(Adepeju, Gbadamosi et al. 2011)* [13] and *(Eleazu and Ironua 2013)* [11]. Each sample was taken 1g to mix with 10ml of pure soybean oil for 60 seconds and set to stand for 10 minutes at room temperature. Weigh the tube before draining at an angle 45° for 10 minutes and then re-weigh to record the final data. Oil absorption was expressed as a percentage increase of the sample weight.

Proximate composition analysis of developed biscuits

Moisture, protein, crude fiber, ash, fat, total carbohydrate content and energy values of prepared biscuits were determined by the same methods used for red corn flour analysis.

Antioxidant activity and Total phenolic content

Extraction preparation of developed biscuits

Blending the developed biscuits into powder. The procedure had been modified to reach the suitable condition in the lab. Briefly, 1g of samples were extracted with 10ml Ethanol 80%. The extract was centrifuged at 5000rpm for 15 minutes at room temperature. The volume after extracting has been recorded for further calculation. The residue was then re-extract 3 times with the same procedure as above and stored at 4ºC for further use. Successive dilutions were made from the stock solution and submitted to evaluate the antioxidant activity and total phenolic content of the samples *(Nguyen, Le, Inoue, Morita, & Pham, 2018)* [14]

Measurement of Antioxidant Activity (DPPH Free Radical Scavenge)

DDPPH (1, 1-diphenyl-2-picryl hydrazine) assay was used to estimate antioxidant activity by *Blois, M. S, 1958*[15]. 1ml of each extract was mixed with 3.9ml of 0.1mM DPPH in Ethanol concentration. It has to incubate exactly 30 minutes in dark at room temperature before measuring in a spectrophotometer with the absorbance at 517 nm. The remaining DPPH free radical was determined by absorbance measurement against Ethanol blanks. The percentage scavenging effect was calculated from the reduction of absorbance against control (DPPH radical solution in Ethanol without sample) using the following equation:

$$\text{Scavenging activity (\%)} = \frac{AbsControl - AbsSample}{AbsControl} x100$$

Determination of Total Phenolic Content

Total phenolics in all samples were determined using Folin-Ciocalteu reagent by spectrophotometer at 750nm according to the method of *Singleton and Rossi (1965)* [16] using Gallic acid as a standard. Standard curve was determined by using the Ethanolic Gallic acid standard solution at concentrations 0;20;40;60;80;100 mg/ml. Briefly, 0.3ml of the extraction (diluted 10 times) or Gallic acid standard was mixed with 1.5ml Folin-Ciocalteu reagent (diluted 10 times) and 1.2ml of Sodium carbonate (Na_2CO_3) (7.5g/100ml) in test tube. The contents of the tubes were mixed thoroughly and stored in the dark for 30 minutes before measuring in a spectrophotometer.

Physical properties measurements of biscuit

In the physical properties, diameter of biscuits was measured by laying six biscuits next to each other with the help of a scale. Then they were rotated 90° to be measured again, the final diameter was the average of these two measurements divided by six. The weight, thickness and spread ratio of biscuits were also measured. For the thickness, its average was determined by placing randomly 6 biscuits on top of the others. Spread ratio was calculated by dividing the average of diameter to the average of thickness *(Drakos, Andrioti-Petropoulou, Evageliou, & Mandala, 2018)* [17] and the density of samples can be determined through the formula which is weight over volume of the biscuits (g/cm^3) *(Monika Thakur, 2018)* [18].

Sensory evaluation

The consumer acceptance of four different samples of biscuits was evaluated by over 60 judges comprising undergraduate students and staff of International University without training. The sensory evaluation test was conducted in the air-conditioned laboratory, which provided a quiet and comfortable environment in the laboratory at International University. The biscuits were served on white disposable plastic trays and tap water was provided for rinsing. Samples were coded with different symbols and the sample order was randomized. Consumers were asked to evaluate the color, taste, aroma, crispness and overall impression of the biscuits using a 9-point hedonic scale ranging from 1 (dislike extremely) to 9 (like extremely) *(Meilgaard, M., 1991)* [19]

Statistical analysis

Data was subjected to analysis of variance using the SPSS version 16.0. Results were presented as means ± standard deviations of triplicate experiments. Significant difference was established at $p \leq 0.05$.

3. Results and Discussions

Proximate analysis of red corn flour

The results of analysis proximate attributes of red corn powder are shown in the Table 2. Also, the same analyzed attributes of wheat flour for a possible comparison.

Table 2: Proximate values of wheat flour and red corn flour

Parameter	Wheat flour	Red corn flour
Moisture %	13.48 ± 0.04^d	9.48 ± 0.03^c
Ash %	0.87 ± 0.29^a	3.49 ± 0.31^b
Protein %	6.54 ± 0.06^a	13.65 ± 0.70^c
Fat %	5.97 ± 0.33^b	5.15 ± 0.13^a

Crude fiber %	ND	2.88±0.01^{e}
Total carbohydrate %	86.62±0.44^{e}	77.71±0.67^{d}
Energy value (kcal)	426.40±2.04^{b}	400.29±0.65^{a}

**Values in the table represent the means ± standard deviations (n = 3 replicates)*

DWB = dry weight basis

ND: Not detected.

a, b, c, d, e: Means with the same column with different letters are significantly different (P<0.05)

As shown in table 2, the fresh Zea mays L. flour has the moisture content with the dry basis weight was 9.48±0.03% which was lower than wheat flour of 13.34±0.04%. Reportedly, the moisture content influences the taste, texture, weight, appearance and shelf life of foodstuffs *(Yvonne Appoldt and Gina Raihani, 2017* [20], the lower flour moisture, the better its storage stability as well as reducing the deterioration of baking quality. Also, the flour with lower than 14% can resist microbial growth and with lower than 9% more restricts the infestation *(Butt, Masood & Nasir, Muhammad & Akhtar, Saeed & Sharif, Mian. (2004))* [21]. Therefore, either wheat flour or red corn flour fall between 0-14% of moisture content which is acceptable for effective flour storage for further processing without the risk of microorganism contamination.

Also, from the table 2, as compared to wheat flour, red corn flour has a high ash content constituted about 3.49±0.31% which is steadily different from the wheat flour ones, 0.87±0.29%. Ash contents indicates the level of minerals present in samples *(Ape, Nwogu, Uwakwe, & Ikedinobi, 2016)* [22]. As compared to recent research about other common maize which are yellow and white corn *(The Proximate, Functional and Anti-Nutritional Properties of Three Selected Varieties of Maize (Yellow, White and Pop Corn) Flour 2017)* [23], ash content of red corn flour is steadily higher than both yellow and white corn flour.

Beside moisture and ash content, protein and fat content are also crucial. The considerable difference in those two values were clearly shown in the table 2. Wheat flour type No.8 has been chosen to make biscuits which leads to lower protein contents than red corn flour. It could be easily seen that the pretty low protein content of wheat flour, comprising 6.54±0.06%, is significantly different from the protein with red corn powder, 13.65±0.70%. This could be advantageous in the formulation of biscuits supplemented with red corn powder. On the other hand, the fat content of red corn flour is nearly as similar as wheat flour which is 5.15±0.13% and 5.97±0.33%, respectively. In fact, wheat flour is a low level of free fatty acids, it is therefore not subjected to rancidity that is important for biscuits formulation *(NDSU Dept. 7670, Sanay Simsek, 2018)* [24]. Red corn flour is low in fat which means it has been connected to decline in the risk of chronic diseases such as obesity, type 2 diabetes *(Siyuan, S., Tong, L., & Liu, R. H., 2018)* [1].
As illustrated by *Marlett, J.A. et al., (2002)* [25] *and Castro, I.S. et al., (2005)* [26], fiber is considered as an efficient protective agent for a wide variety of illnesses, including cardiovascular disease, colon cancer, and constipation. In order to increase the consumption of fiber, the American Dietetic

Association (ADA) recommended the mushrooms is one of four types of food (a variety of grains, vegetables, and fruits) is included to add in daily diets for an active and healthy life *(Johnson, R.K. and Kennedy E. 2000)* [27]. As shown in the Table 2, wheat flour owns nothing of crude fiber value that data showed not detected result. In contrast, the obtained result from analysis of red corn powder was accounted for 2.88±0.01% on a dry weight basis.

From the Table 2, data on the total carbohydrate content of both flours displayed the highest value in all proximate compositions. Wheat flour’s total carbohydrate value is significantly higher than the Red corn flour one which is allocated at around 86.62±0.44% and of 77.71±0.67%, respectively. Also, according to the research about 3 common types of corn which are white, pop and yellow corn. It is claimed that fat content of these three are 12.9%, 14.2% and 13.5%, respectively *(The Proximate, Functional and Anti-Nutritional Properties of Three Selected Varieties of Maize (Yellow, White and Pop Corn) Flour 2017)* [23], while red corn flour has a significant lower which could replace those three corns as a higher level of benefit for consumer's health as well as it is suitable to be a supplement for food products. Moreover, red corn flour also has more crude fiber content than them which means it could reduce the risk of consuming too much fat and provides consumer with more fiber to prevent from some chronic diseases.

Functional properties of composite flours

The results of the functional properties of red corn powder sample and flour blends including wheat and Red corn flour are presented in Table 3 consisting of bulk density, water absorption capacity, oil absorption capacity. Functional property is defined as any property of a food or food ingredients, beside its nutritional value that affects its utilization. These functional properties: bulk density, water absorption capacity (WAC), oil absorption capacity (OAC) which may become one of the effects of the behavior of food systems during storage *(Shobha et al., 2012)* [28].

Table 3: Effect of incorporating Red corn powder on the functional properties of the composite flours

Samples	Bulk density (g/cm^3)	Water Absorption Capacity (g/g)	Oil absorption capacity (g/g)
W	0.67 ± 0.32^{a}	0.1^{b}	0.91 ± 0.06^{cD}
WB	0.68 ± 0.35^{a}	0.1^{b}	0.92 ± 0.06^{d}
WC	0.69 ± 0.4^{a}	0.097 ± 0.06^{aB}	0.89^{a}
WD	0.68 ± 0.15^{a}	0.097 ± 0.06^{aB}	0.89 ± 0.06^{aB}

**Values in the table represent the means ± standard deviations (n = 3 replicates).*
a, b, c, d: Means with the same column with different letters are significantly different (P<0.05)
A, B, C, D: *Means with the same row with different letters are significantly different (P<0.05)*
W (control) = 100:0, 100% wheat flour
WB = 95:5, 95% of wheat flour incorporated with 5% of red corn flour blends
WC = 90:10, 90% of wheat flour incorporated with 10% of red corn flour blends
WD = 85:5, 85% of wheat flour incorporated with 5% of red corn flour blends.

Table 4: Functional properties of red corn flour

Physical property	Value
Bulk density (g/cm^3)	0.7 ± 0.32
Water Absorption Capacity (g/g)	0.09
Oil absorption capacity (g/g)	0.91 ± 0.06

**Values in the table represent the means ± standard deviations (n = 3 replicates).*

Bulk Density

The bulk density of flour is the density measured without the influence of any compression. As shown in the table 4, value of red corn flour is 0.70 g/cm^3 compared to 0.67 g/cm^3 of wheat flour that they are not significantly different which means red corn flour has similarity bulk density to wheat flour. As this result, it was clear that the incorporation of red corn flour with wheat flour in 5%, 10%, 15 % illustrate a stable trend of 0.68 g/cm^3, 0.69 g/cm^3, 0.68g/cm^3, respectively. The particle size and the density of the food affect the bulk density of food materials. Bulk density is an important factor in food packaging *(Adelakun Oluyemisi Elizabeth, 2017* *[29]*. According to *Oladele and Aina, 2009[30]*, lower bulk density of the discussed flours has been reported to be useful for food formulation when used for complementary foods *(Akapata and Akubor, 1999)* *[31]*. Moreover, low bulk density is desirable in infant feeding *(Iwe and Onadipe, 2001)* *[32]* and low bulk density food is desired where packaging is a serious problem *(Ikujenlola, 2008)* *[33]*.

Water Absorption Capacity (WAC)

The water absorption capacities affect the quality of baked goods and depend partly on the damaged starch contained in the flour, the protein content and particle size *(Kulkarni KD, 1991)* *[34]*. Water absorption capacity is an important functional characteristic in the development of ready to eat food from cereal grains, since high water absorption capacity may assure product cohesiveness *(Shobha et al., 2012)* *[28]*. As illustrated in Table 3 and table 4, Water absorption capacities of 0.09 g/ml, 0.1 g/ml, 0.1 g/ml, 0.097 g/ml and 0.097g/ml were obtained for red corn flour, wheat flour and incorporation of red corn flour with wheat flour in 5%, 10%, 15 %, respectively. This result is much lower than the relevant research about WAC of white corn, yellow corn and popcorn which are 2.11g/ml, 1.98g/ml and 2.32g/ml, respectively *(Makanjuola Olakunle & Makanjuola John, 2018)* *[35]*

The water absorption capacity represents the ability of a product to associate with water under conditions where water is limited. The amount of water associated with starch granules influences the swelling characteristics of the granules *(Singh, 2001).* The amount of water absorbed depends primarily on the availability of two types of hydrophilic groups which are capable of binding water through bond formation. Water absorption capacity of flour is an indication of the amount of water available for gelatinization and a useful indication of whether protein can be incorporated with aqueous food formulations especially those involving dough handling such as processed cheese, sausages and bread *(Edema et al., 2005., Osungbara et al., 2010).*

Oil Absorption Capacity (OAC)

OAC is exhibited by the proteins in the flour which physically bind to fat by capillary attraction. Not only for biscuits making, but OAC also plays a significant role in ground meat formulations like sausages and to increase the shelf life of meat products *(Akinyede, A. I, 2009)* *[36]*. As seen in the table 4, red corn flour recorded 91% of OAC, among four flour blends, data on the flour blend WB was found the highest value which was significantly different to the sample WC and WD with 10% and 15% of red corn powder adding which amounted approximately 89%. About sample WA and WD, both allocated 91% and 92%, respectively, that were the insignificant difference. It could be attributed that the higher the oil absorption capacity of a flour sample, the better the cookie quality. However, in this study, we could observe the reverse data which could explain from the low percentage of red corn flour.

Oil absorption capacity characteristic is required in ground analog, doughnut, pancakes, baked foods, and soups. Absorption of oil by food products improves mouth feel and flavor retention. Oil retention also improves the quality of biscuits because oil contributes to the soft texture of cookies *(Jacob and Leelavathi, 2007)* *[35]*. The higher OAC in flour blend, the more improvement of palatability and extension of shelf life particularly in biscuit products where fat absorption is desired *(Aremu et al. 2007)* *[36]*. The major chemical component affecting OAC is a protein which is composed of both hydrophilic and hydrophobic parts *(Jitngarmkusol et al. 2008)* *[37]*. Hence, the flour blend B is ideal in biscuits making.

Physical properties of developed biscuits

Diameter, thickness, spread ratio and density of biscuits are five physical parameters recorded in the table 5. to study the effect of replacing 5%, 10% and 15% of wheat flour with red corn powder.

Table 5: Effect of Red corn powder on the physical parameter of biscuits

Physical properties	A	B	C	D
Diameter (cm)	5.86 ± 0.18^a	6.01 ± 0.15^a	5.95 ± 0.07^a	6.04 ± 0.13^a
Thickness (cm)	3.6 ± 0.2^a	3.83 ± 0.27^a	3.82 ± 0.14^a	3.7 ± 0.3^a
Spread ratio (cm)	1.63 ± 0.05^b	1.57 ± 0.04^a	1.56 ± 0.02^a	1.65 ± 0.04^b
Density (g/cm3)	0.13 ± 0.01^a	0.12 ± 0.01^a	0.013 ± 0.01^a	0.12 ± 0.01^a

**Values in the table represent the means ± standard deviations (n = 3 replicates).*

The values denoted by different letters in the same column are significantly different ($p \leq 0.05$)

A (control)= 100:0, 100% wheat flour biscuits
B= 95:5, 95% of wheat flour incorporated with 5% of Red corn biscuits
C= 90:10, 90% of wheat flour incorporated with 10% of Red corn biscuits
D= 85:5, 85% of wheat flour incorporated with 5% of Red corn biscuits.

As displayed in the Table 5, a supplement of red corn powder at different proportions did not produce a significant change in physical characteristics. To be more specific, diameter shared the similarity of diameter which ranged from 5.86 centimeter to 6.04 centimeter which is the average diameter of commercial biscuit products.

In terms of biscuits' thickness, due to the thickness being measured by placing 6 biscuits with the same sample on top each other, the results are higher than the other research which are between 3.6 cm and 3.8 cm. Especially, there is no sharp difference between biscuit 5% and 10% red corn powder sharing approximately 3.8 cm.

As table 5 illustrated, while biscuit B and C got a similar result of spread ratio, control one and sample D are nearly the same which also has the highest value in the same parameter. Spread ratio of biscuit is an important quality parameter, it is used to determine the quality of flour used in preparing biscuits and the ability of the biscuit to rise *(Bala et al., 2015)* [38]. The higher the spread ratio of biscuit the more desirable it is *(Chauhan, Saxena, & Singh, 2016)* [39]. Hence, biscuits A prepared from 100% wheat flour and biscuit D prepared from 15% of red corn powder may be demonstrated the most preferred based on spread ratio that allocated approximately 1.65 cm and was significantly different from biscuits B and C. Besides, spread ratio was calculated by dividing diameter to thickness meaning thicker biscuit will lead to lower spread ratio. As discussed above, the thickness is determined by a six-biscuit-heap which is a reason for lower spread ratio than other research about biscuit. Moreover, in other studies reported, the lower spread-ratios of biscuits can be attributed to the samples containing more water absorbing constituents like protein and fiber. Several reports *(Patel et al., 1996; Hooda et al., 2005)* [40] revealed that reduced spread ratio was observed when wheat flour was replaced by either high protein or high fiber ingredients. These constituents form aggregates with available hydrophilic sites thus reducing free water in biscuit dough *(McWatters, 1978)* [41]. Rapid partitioning of free water of these hydrophilic sites occurs during dough mixing and increases dough viscosity relating to limitation of biscuit spread. Therefore, the lower spread ratio characteristic as biscuits B and C are useful to increase their suitability for rotary mold *preparation* in which a lower spread is desirable to keep the embossing complete *(Hooda et al., 2005)* [42].

Density was supposed the best index of the organoleptic texture of biscuits. In addition, according to *Manohar and Rao (2002)* [43], there was a positive relationship between dough firmness and density. As reported in Table 5, data on the four biscuits again were significantly different which shared between 0.12 g/cm^3 and 0.13 g/cm^3. From *Chetan Gupta, 2015*[44] perspectives, density is greatly influenced by the particle size of flours. Flours with finer particle size when applied to make hard doughs give biscuits with a higher density and result in less development during baking *(Manley, 2000)* [45]. Thus, biscuits A, B, C and D were believed to own an enough desirable crispiness and textural aspects due to lower density values *Manohar and Rao (2002)* [43]. On the one hand, several works on biscuits prepared with composite flours can be found in literature. The general trend reported is that wheat flour substitution is accompanied by an increase in weight and a decrease in spread ratio (e.g. Hooda and Jood 2005[42]; Zucco et al. 2011).

Proximate values of developed biscuits

Table 6 presents the nutritional composition of biscuits prepared from the composite flour of wheat flour substituted with red corn powder at different ratios 5%, 10%, 15% compared to the control sample (biscuits A).

Table 6: Proximate composition values of developed biscuits

Parameter	A	B	C	D
Moisture %	2.66 ± 0.28^{a}	3.16 ± 0.28^{b}	3.00 ± 0.006^{aB}	3.32 ± 0.27^{b}
Ash %	0.86 ± 0.3^{a}	1.20 ± 0.3^{a}	1.38 ± 0.3^{a}	1.72 ± 0.54^{a}
Protein %	8.33 ± 0.66^{b}	8.55 ± 0.16^{b}	8.75 ± 0.09^{b}	9.03 ± 0.07^{b}
Fat %	23.55 ± 0.45^{e}	16.84 ± 0.52^{c}	16.46 ± 0.46^{c}	18.04 ± 0.005^{d}
Crude fiber %	ND	0.15 ± 0.06^{b}	0.22 ± 0.006^{d}	0.17 ± 0.006^{c}
Total carbohydrate %	67.26 ± 0.8^{a}	73.41 ± 0.44^{c}	73.41 ± 0.43^{c}	71.21 ± 0.6^{b}
Energy value (kcal)	514.32 ± 1.28^{e}	478.76 ± 3.32^{c}	475.94 ± 0.96^{cD}	482.62 ± 2.11^{d}

**Values in the table represent the means ± standard deviations (n = 3 replicates). The values denoted by different letters in the same column are significantly different (p ≤0.05); ND: Not detected.*

A (control) = 100:0, 100% wheat flour biscuits
B = 95:5, 95% of wheat flour incorporated with 5% of Red corn biscuits
C = 90:10, 90% of wheat flour incorporated with 10% of Red corn biscuits
D = 85:5, 85% of wheat flour incorporated with 15% of Red corn biscuits.

There was a significant ($P \leq 0.05$) difference in the moisture contents of all the biscuits made from the substituted samples. The results indicated that adding the red corn powder to prepared biscuits caused a significant ($P \leq 0.05$) increase in their moisture contents ranging from 3.00% to 3.32% compared to control biscuit which gave 2.66%. The moisture content of all biscuits was low enough (<10%) to reduce the chances of spoilage by microorganisms and consequently guarantee good storage stability (Ayo et al., 2007) [46]. The difference between them is mostly due to different baking conditions, environmental issues and moisture absorb ability of the ingredients in different conditions.

The fat content of the biscuit was ranged from 18.04% to 23.55% with 100% wheat flour having the highest fat content and biscuit with 95% (B) and 90% wheat flour (C) having the lowest. While the biscuit sample all three biscuits added red corn powder showed a significant difference to the control ones, biscuits sample B and C are not significantly different with each other. There are a variety of observations in fat contents of the biscuit samples, despite using the same quantity of fat in the ingredient as well as it might be due to the difference in their moisture contents. The fat content of the developed biscuits met the standard value (15%-20%) for soft dough biscuits *(Manley, 2001)* [47]. Also, according to the table 6, the fat content is higher than the protein content which could be explained by the original red corn powder used in biscuits formulation contains 5.15% (Table 6). In terms of flavor and texture, the high calorific value could also serve as a lubricating agent that improves the product's quality which stems from the presence of high fat content in samples. In addition, fat is a rich source of energy and is essential as carriers of fat-soluble vitamins; A, D, E and K *(Ihekoronye & Ngoddy, 1985).* As a result, although these samples are high in fat content compared to protein, biscuits incorporated with red corn flour are desirable for production. Moreover, from the table 6 biscuits B, C, D owning fat results do not exceed 25% which lead to preventing rancidity in food or unpleasant and odorous compounds *(Ihekoronye & Ngoddy, 1985).*

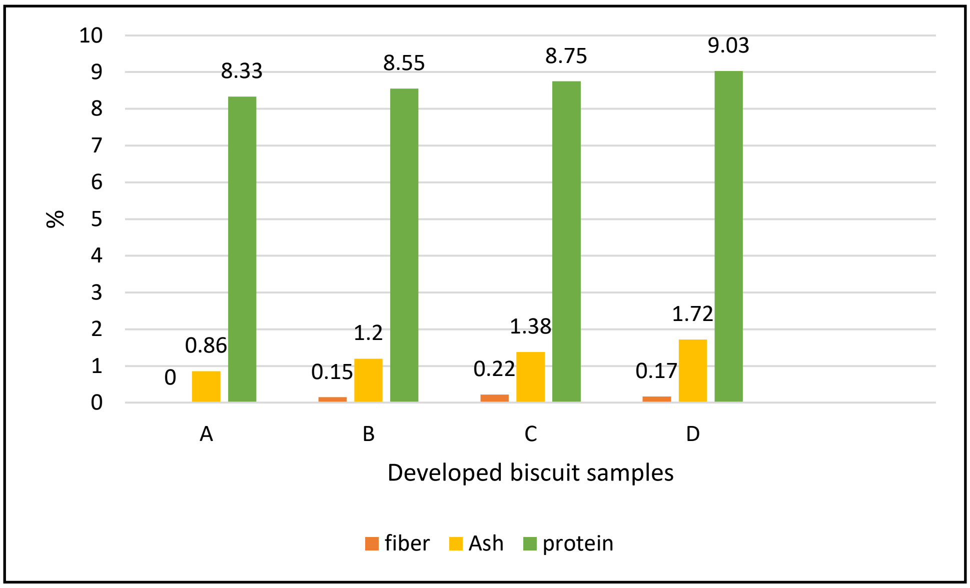

Figure 3. Effect of incorporating different ratio of red corn flour on Fiber, Ash and Protein content of biscuits.

From the chart above, it is easy to recognize that sample D was recorded dramatically increase in ash contents being 1.72% compared to the control sample with 0.86%. Beside that sample B and C were all higher than the control ones because of the high in ash content of original red corn powder that was used in each sample. Also, the combination between red corn flour and wheat flour in formulation B, C, D promoted a slight increase in protein content. This result stems from the addition of a various level of red corn flour in biscuits. Also, this incorporation is the desirable increasing rate of protein values that biscuits may contain essential amino acids.

It is reported by *Chavan, J. K., 1993*[48] that biscuits and cookies are common to be consumed by customers, however they have a low nutritional value. From table 6 and figure 3. Although red corn flour does not contain a very high fiber as compared to other vegetables, it is considered higher than wheat flour. Due to this result, biscuits B, C, D contained a certain proportion of fiber while the control one did not detect any fiber value. There was an upward trend in fiber value of biscuits following the rise in the percentage substituted of red corn powder. Therefore, sample D is recorded with the highest ones. In this research, the dietary fiber content of the samples was not determined, however the values obtained from crude fiber analysis indicated that the formulations B, C, D could be considered fiber-rich products *(BEATRIZ CERVEJEIRA BOLANHO, 2014)* [49]. According to *BILGIÇLI et al., 2007*[50] several sources of fiber can be used in biscuits production in order to improve their texture, color, flavor and decrease the energy value. Fiber intake has a positive impact on human health, as it can act by slowing down hydrolysis, digestion, and absorption in the small intestine, increasing the volume of stools and reducing levels of glucose and cholesterol absorbed from the lumen *(Elleuch, M, 2011)* [51].

As shown in the table 6, it is generally high in carbohydrate contents which range from 67.26% to 73.41%. There is no significant difference among 5% (B) and 10% (C) Red corn-based biscuits that share 73.41% which is also the highest value of carbohydrate contents. Beside that biscuits C is recorded with 71.21% which is higher than control one and shares a similarity with other 2 samples. Therefore, biscuit B and C are rich in carbohydrate content that is an ideal supplement for marasmus patients *(Helen Obioma Agu, 2014)* [52].

The amount of calories available from food through oxidation is energy content, the presence of total protein, fat, and carbohydrates in food are contributed to energy content *(Abiodun A. Adeola, 2018)*[53]. The calorific values for the biscuits (Table 6) varied from 475.94 kcal in biscuits C to 514.32 kcal on a dry weight basis in biscuits A. The energy content of the biscuit samples increased as the protein content decreased. This was in conformity with reported trends *(Iwe, Van Zauilichem, Ngoddy, & Ariahu, 2001)* [32] *a*s the table 6 reported. When the protein content of 100% wheat flour biscuit was the lowest, then it had the highest energy value. Although biscuit D has the highest protein content, it is recorded with the second highest one of energy value which is 482.62% but it is not significant with sample C at the same row. The biscuits added with red corn flour might be affected by the original red corn one with lower energy result compared to the wheat flour. Biscuit could give energy for consumers that are both young and old *(Manley, 2001)* [47].

Antioxidant assay and Total Phenolic Content in developed biscuits

It is known that maize has a great source of total phenolic and free radical scavenging activity. However, red corn flour is new in the food industry which still has less research about it. In the discussion below, it will be shown a significant difference in total phenolic compounds that was accompanied by an elevation in the scavenging activity between red corn powder sample and biscuit formulations.

Table 7: DPPH scavenging activity and total phenolic content (TPC) of developed biscuits

Sample	Scavenging activity (%)	Total phenolic content (μ g GAE/ g)
Red corn	46.240 ± 0.855^{d}	1370.63 ± 15.09^{e}
A	$5.46s \pm 0.708^{a}$	234.32 ± 0.68^{a}
B	21.339 ± 0.095^{b}	600.88 ± 5.23^{b}
C	21.659 ± 0.448^{b}	974.94 ± 4.42^{c}
D	27.397 ± 0.228^{c}	1215.23 ± 7.35^{d}

**Values in the table represent the means ± standard deviations (n = 3 replicates)*

a, b, c: Means with the same column with different letters are significantly different (P<0.05)

A (control)= 100:0, 100% wheat flour

B= 95:5, 95% of wheat flour incorporated with 5% of Red corn flour blends

C= 90:10, 90% of wheat flour incorporated with 10% of Red corn flour blends

D= 85:5, 85% of wheat flour incorporated with 15% of Red corn flour blends.

DPPH radical scavenging activities

Corn has the highest total antioxidant activity among all common grains such as rice, wheat and oats. Phytochemicals are the major contributors to the total antioxidant activity in corn *(Siyuan, Tong, & Liu, 2018)* [1]. Antioxidants have already been found in plant materials and supplements. Due to their natural origin, the antioxidants obtained from plants are of greater benefit in comparison to synthetic ones *(ROHMAN et al., 2010; ZHENG and WANG, 2001).*

As shown in table 7, the red corn powder added biscuits formulation showed a significant increase in the antioxidant potential towards the DPPH free radical. The antioxidant activity of raw red corn powder was the highest result following biscuits D, C, B and the last one is A that allocated 46.24%, 27.39%, 21.6%, 21.3% and 5.46%, respectively.

By their free radical scavenging capacities, all the levels of red corn powder incorporated in biscuits showed a good ability in radical scavenging activity (21.3% - 27.39%), while it was only 5.46% in the case of the control. There was a gradual upward trend in the higher incorporation of red corn flour into biscuits had significantly elevated the antioxidant activity for few folds compared to the original control biscuits without red maize flour added. Thus, these results reveal the importance of supplementation of biscuits with red maize flour that biscuit products can be considered as a functional food ingredient because of their antioxidant properties.

Total Phenolic Content

Regarding the most important group of phenolic compounds, approximately 60 percent of polyphenols are flavonoids. The other is anthocyanins, the chemical compounds which responsibles for the red of this maize and are in the pericarp or aleurone of the grain (Herrera-Sotero et al., 2017) [54]. The content of phenolic compounds of red corn flour and grinded developed biscuits extraction was determined by Folin-Ciocalteu procedure with some modification (Nguyen, Le, Inoue, Morita, & Pham, 2018) [14] , using Gallic acid as a standard. Absorbance was measured at 765 nm. The content of total phenolic compounds has been expressed as mg of gallic acid equivalent (GAE) per g of the extraction (mg GAE/g).

In this study, the phenolic content of red corn powder sample and developed biscuit with different ratio of red corn powder addition was investigated and given in table 7. The Red corn powder was reported 1370.63 µg GAE/g which is lower than the work done by (Lopez-Martinez et al., 2009) [56] . According to Zuofa zhang, 2009[55] different drying treatments affected the TPC result that oven heating at 50°C was shown to rapidly inactive polyphenol oxidase present in plant materials, however, some of their initial activities may have occurred earlier and caused some polyphenols to be degraded (z. zhang et al., 2009) [55]. Beside that Okuda et al. (1989) [55] have mentioned that rosmarinic acid was degraded when it is dried in direct sunlight, and in the oven at the temperature varied between 60°C and 80°C. Interestingly, in the z. Zhang et al., 2009[55] studies, freeze-drying of Shiitake showed higher TPC and DPPH scavenging activity. For freeze-drying, there is no thermal degradation and neither does the process allow degradative enzymes to function (Chan et al., 2008) [58] . Furthermore, freeze-drying is known to have high extraction efficiency because ice crystals formed within the sample matrix can rupture cell structure, which allows exit of cellular components and access of solvent, and consequently better extraction (Asami and Hong, 2003) [59] .

As pointed out in Table 7, data on TPC increased gradually following the rising addition of red corn flour levels. To be specific, biscuits D was the highest value which shared 1215.23 µg GAE/g. All three biscuit samples incorporated with red corn powder exhibited a significant level of TPC of the products compared to the control samples. The TPC (µg GAE/g) in the different varieties of the sample extracts were calculated using the standard curve for Folin with the equation $y= 0.2369x - 0.1688$, $R2= 0.9993$ In the supplemented red corn powder biscuits, TPC ranged between 600.88 and 1215.23 µg GAE/g, while the result of the control sample was 234.32 µg GAE/g. These concentrations were statistically different ($p < 0.05$) among the studied samples.

Sensory evaluation

Sensory evaluation of the biscuits depends on its first color, aroma, crispiness, taste and overall impression of the sample. Table below shows if the results are significantly different or not from organoleptic acceptability of biscuits on 9 points Hedonic scale was given by 62 untrained panelists from international university staff and students.

Table 8: Sensory evaluation scores of developed biscuits in terms of color, aroma, crispiness, taste and overall impression in 9 - point scale.

	A	B	C	D
Color	7.67 ± 0.837^{b}	6.38 ± 1.197^{a}	6.03 ± 1.284^{a}	6.00 ± 1.217^{a}
Aroma	7.1 ± 1.28^{c}	6.85 ± 1.123^{bC}	6.32 ± 1.32^{aB}	6.19 ± 1.29^{a}

Crispness	7.37 ± 0.956^{b}	6.92 ± 0.80^{aB}	6.73 ± 1.07^{a}	6.5 ± 1.23^{a}
Taste	7.2 ± 1.176^{b}	7.43 ± 1.125^{b}	7.29 ± 1.062^{b}	6.52 ± 1.035^{a}
Overall impression	7.32 ± 0.97^{c}	7.1 ± 0.95^{bC}	6.76 ± 1.01^{b}	6.24 ± 1.05^{a}

*Average of 62 evaluations. The values denoted by different letters in the same column are significantly different ($p \leq 0.05$)

The results for sensorial color acceptance from Table 8 showed that formulation of the original biscuits which made from 100% wheat flour had the highest score that was more than 7 points. However, the biscuits D displayed the significantly lowest score, 6.00, for the color which means more panelists prefer lighter color for biscuits' appearance. It is noticed that the higher proportion of red corn flour in formulation is, the darker color of the biscuit samples is, because of the light darkness of red corn flour. This stems from traditionally people suppose for light yellow related to the rich-butter color is stunning. From the result, biscuits with 5% and 10% Red corn flour incorporated biscuits are acceptable with lighter dark. However, the increase in darkness was reflected in biscuit D may decrease appetite because people may suppose bitter taste, over temperature. Color attribute is a major criterion that affects the quality of the baked products. Color is a very important parameter in judging properly baked cookies that not only reflect the suitable raw materials used for the preparation but also provides information about the formulation and quality of the product *(Ikpeme et al., 2010)* *[60]*. Also, the color development is contributed by the Maillard reaction between sugars and proteins of product that results in brown color *(Singh et al., 1993)* *[61]*. Other factors that may be responsible for color development are time and temperature of baking, composition, humidity in the oven etc. *(Lingnert, 1990)* *[62]* and *(Wade, 1988)* *[63]*.

According to the Table 8, the taste of biscuit B and C was insignificantly different from the control one which are 7.43 and 7.29, respectively which gave us the highest score as the most preference from the panelists. Thanks to 5% and 10 % of red corn powder, they create a nutty and cereal feeling while chewing biscuits. For the original biscuits and the other maize biscuit, we usually can not recognize this taste. Next, as biscuit D with 6.52 which is also the lowest score compared to the rest, this could result from a bit bitter taste and the cereal taste covers all the butter and sweet taste that make some people feel strange and could not adapt this taste.

Similar to the taste, sample D also got the lowest score of the aroma from the panelists and shared a significant difference from each other. Sample B and C had the acceptable point which indifferent score from the 100% wheat flour biscuit. However, all developed biscuits ensured the crispness of the normal biscuits which showed insignificantly different scores. This is the strength of these supplement biscuits because crispness is a desired characteristic that makes customers subscribe to purchasing any biscuits *(Lusas and Rooney 2001)* *[64]*.

From the individual factor above, the general impression for biscuits control, B and C were not significantly different sharing in the range between 6.76 and 7.32 within the rate of like slightly and moderately like. As displayed in the Table 8, biscuits D was sharply lowest one allocating 6.24 for the impression but it rated slightly like this 15% Red corn powder biscuits because there is a minority of people like its strange taste and aroma. Therefore, all three developed biscuits got moderately like from people, especially 5% and 10% Red corn powder added is much more desirable than the rest. The 5%, 10% and 15% addition of red corn flour are acceptable to consumers.

Conclusions

In this study, the incorporation potential of the wheat flour with red corn powder in biscuits production to improve nutritional values and the development of new recipes to make good quality biscuits from Red corn were successfully and thoroughly investigated.

- ✓ The nutritional analysis of the wheat flour - red corn powder biscuits showed the dominance of fiber, protein, ash from 15% Red corn flour enriched biscuits by selected supplements.
- ✓ The total phenolic content and antioxidants of all three ratios of red corn powder added biscuits were significantly higher than the control ones.

- ✓ Based on the organoleptic evaluation, substitution of up to 5% and 10% of wheat flour with red corn powder improved the most acceptable sensory characteristics of prepared biscuits compared to wheat biscuits.

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