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Investigating on Production Healthy Snack Food Based on Cereal by Type III Resistant Starch Addition

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ABSTRACT

Resistant starches are classified in the category of indigestible starches and are introduced as a prebiotic product, which has lower calories and is cheaper compared to other dietary fibers. Therefore, the purpose of this research is to use type III resistant starch produced by thermal method at levels of 0, 5, 10, 15, 20, 25 and 30% in a completely random design as a substitute for wheat flour in biscuit, doughnut and cookie formulation. The results showed that by replacing wheat flour with resistant starch in the formulation more than 20%, the moisture content and water activity of the final product increased and decreased respectively. The specific volume and porosity of the doughnut were stable up to the level of 15% of resistant starch and then decreased. Also, the sample containing 15% resistant starch had the lowest amount of firmness in all the products. On the other hand, with the replacement of resistant starch in the formulation of the examined products on levels of 15% and above, the amount of L* value increased and the a* and b* values were decreased. The panelists also introduced the sample containing 15% resistant starch as the best sample. Therefore, it can be said that by replacing 15% of wheat flour with resistant starch, in addition to maintaining the physicochemical, textural and sensory characteristics of the final product, it is possible to enrich these snacks and the consumer can benefit from the benefits of using prebiotic products.

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1- Introduction

to starches that are not digested due to the action of hydrolyzing enzymes in the small intestine, but are fermented in the large intestine under the influence of bacteria and produce various products such as short-chain fatty acids butyric acid and propionic acid, carbon dioxide and hydrogen gases, and sometimes methane It is called resistant starch. According to the production of butyrate, propionate and acetate during the fermentation of resistant starch, which is used as a substrate and energy source for the growth of probiotics.[1] and clone cells, resistant starch as a prebiotic product[2] is introduced [1]. Among the most important health effects of resistant starch are the beneficial effects on the health of the intestines and the prevention of colon cancer through fermentation by microbial flora and the production of small amounts of gas, reducing the level of intestinal pathogens, increasing the frequency and volume of stools, reducing the symptoms of diarrhea and Prevention of hemorrhoids and constipation, etc. In addition to the beneficial role of resistant starch in consumer health, it also has positive technological properties in food formulation [2]. Unlike dietary fibers, resistant starch improves food quality, such as increasing crispiness, reducing oil in fried products, etc. Unique features of resistant starch, such as its natural source, small particle size, white color, pleasant sweet flavor, water binding capacity.[3] Lower and water holding capacity[4] Higher than dietary fibers, high gelatinization temperature and good extrusion properties have made it a valuable supplement in a wide range of foods [3 and 4].

Resistant starch is produced by different physical, chemical and enzymatic methods. The physical methods include thermal, enzymatic, thermal-enzymatic and radiation methods. Thermal processes such as autoclaving, boiling, steaming, microwaving, extruding are physical methods of producing resistant starches [2]. Wet cooking or thermal process increases the production of resistant starch by accelerating and intensifying the retrograde process. In this regard, Tsatsarako et al. (2015) investigated the effect of adding resistant starch on gluten-free cake based on rice flour and tapioca starch and stated that the specific volume of the cake increased with the increase in the amount of resistant starch and the highest specific volume was at the level of 15%. seen. In addition, the analysis of the cake slices showed a decrease in the surface porosity and the number of pores and an increase in the average diameter of the pores along with an increase in the concentration of resistant starch. During the storage period of the cake, the cake crust remained softer in the formulation containing a higher amount of resistant starch. The taste judges also assigned the highest score to the sample containing 20% resistant starch [5]. In addition, Majzoubi et al. (2014) investigated the effect of resistant corn starch on the physicochemical properties of the cake. The results showed that by increasing the level of resistant starch, dough endurance increased while its density decreased. On the other hand, the density and volume of the produced cake samples increased and decreased respectively. The resulting cake became softer, but its stickiness, elasticity and chewability decreased. Also, the color of the cakes became whiter, but their redness and yellowness decreased [6]. Laguna et al. (2011) also investigated the use of resistant starch on the baking quality of short dough

[1] - Probiotic
[2] - Prebiotic
[3] - Water-binding capacity
[4] - Water-holding capacity

biscuits. In this research, wheat flour was replaced with resistant starch at levels of zero (control sample), 20, 40 and 60%. The results showed that the addition of resistant starch had an effect on the strength of the raw dough and the ease of slicing and cutting. Regarding the edible quality of the final product, the addition of resistant starch increased the force required for breaking and crushing and decreased the penetration resistance [7].

Therefore, according to the mentioned materials, the purpose of this research was to investigate the effect of the use of type 3 resistant starch produced from corn at different levels on the quantitative and qualitative characteristics of some baking industry products (donuts, biscuits and cookies). which are used as popular snacks among people in the society.

2- Materials and methods

Star flour with an extraction degree of 82% was purchased from Tehran Bakhtar Flour Factory (Tehran, Iran) and corn starch was also purchased from Nab Fruitor Processing Company (Nazarabad, Alborz). For this purpose, the flour and starch samples required for the experiments were prepared at once and kept in a cold room at a temperature of 4 degrees Celsius. Yeast used (*Saccharomyces cerevisiae*) which was in the form of active dry yeast powder and vacuum packed, was obtained from Razavi Yeast Company (Mashhad, Iran). Other ingredients and ingredients needed for the preparation of all three products were also purchased from reputable confectionery stores.

1-2- Examining the characteristics of wheat flour and corn starch

First, the chemical characteristics of wheat flour used in the production of donuts, biscuits and cookies, as well as corn starch to produce resistant starch based on AACC standard methods.[5] (2000) was measured [8]. The amount of moisture using the oven method is number 16-44, the amount of ash is using the base method is number 01-08, the amount of protein is using the Keldall method is number 46-12, the amount of fat is using the approved method 30-10 and Wheat flour gluten was determined using the approved method of 38-11.

2-2- Production of resistant starch

In order to produce resistant starch, natural starch was first produced from corn kernels by wet milling method. Then this natural starch was used to produce the third type of resistant starch according to the method of Dander and Gassman (2013), in this way, a 1:4 suspension of starch and distilled water was prepared, then it was cooked for 30 minutes on a stirring heater and then It was autoclaved at 121 degrees Celsius for 45 minutes. After that, the samples were cooled at room temperature and after temperature equilibrium with the environment, the starches were stored for 72 hours at 4 degrees Celsius. Finally, the starch samples were dried in an oven at 45 degrees Celsius and when the moisture content of the samples reached 10-12%, the samples were ground and passed through a 100 mesh sieve [1].

2-3- Production of cereal-based snacks

doughnut: Donuts were prepared according to the method of Etziri et al. (2015). Donut ingredients include 55% wheat flour, 5% sugar, 10% eggs, 5% oil, 18.5% water, 3% yeast, 0.2% vanilla, 2.8% powdered milk, and 0.5% salt. Was. In the formulation of different treatments, resistant starch type 3 was substituted for wheat flour at levels of zero, 5, 10, 15, 20, 25 and 30%. After preparing the dough, it was rolled out to a thickness of one centimeter and molded. The parts are

[5]- American Association of Cereal Chemists (AACC)

fermented for 90 minutes at a temperature of 45 degrees Celsius and a relative humidity of 85% in a fermentation chamber.Zuccihelli Froni, made in Italy), passed the second stage of fermentation. At the end, samples of donuts inside the fryer (trees, made in Germany) containing frying oil were fried and after frying, the excess oil was removed by oil absorbent paper and packed in polyethylene bags and kept at room temperature (dry and cool) until The completion of each test was maintained [9].

Biscuits: Biscuit was prepared according to the method of Soda et al. (2007).The formulation of the control sample contains 63% wheat flour (control), 8% sugar, 10% water, 11% shortening, 3% dextrose, 2% powdered milk, 1% salt, 0.8% sodium bicarbonate, 0.9 The percentage of ammonium bicarbonate and essential oil was 0.3%. In the formulation of different treatments, resistant starch type 3 was substituted for wheat flour at zero (control sample), 5, 10, 15, 20, 25 and 30% levels. After mixing the ingredients, the biscuit dough was spread to a thickness of 8 mm with the help of a rolling pin on the flat surface of the tray and cut into 70 mm diameter by circular metal molds. In the continuation of the cooking process in the hot air oven (Zuccihelli Froni, made in Italy), at a temperature of 220 degrees Celsius and a duration of 15 minutes. Finally, after cooling the biscuit samples in the trays and at ambient temperature, they were packed in polyethylene bags and kept at room temperature (dry and cool) until each test was performed. [10].

Cookies: Cookies were prepared by the method of Haqaiq and Zavehzad (2016). For this purpose, the basic ingredients of the cookies included 52% wheat flour (control), 25% sugar, 10% oil, 7% water, 5% eggs, 0.6% salt, and 0.4% baking powder. In the formulation of different treatments, resistant starch type 3 was substituted for wheat flour at zero (control sample), 5, 10, 15, 20, 25 and 30% levels. After mixing the ingredients, the dough entered the cutting stage and after passing through the rollers (thickness 15 mm) and molding (diameter 8 cm), the baking process in the hot air oven (Zuccihelli Froni, made in Italy), at a temperature of 170 degrees Celsius and a duration of 10 minutes. After cooling the cookies at ambient temperature, they were packed in polyethylene bags and kept at room temperature (dry and cool) until each test was performed [11].

2-4- Evaluation of quantitative and qualitative characteristics of snacks

The characteristics of the final products were evaluated according to the following methods:

Humidity: Measuring the moisture content of biscuit, donut and cookie samples using the AACC standard, 2000 No. 16-44 using an oven (Let's go Tech, made in South Korea) was done [8].

Water activity: The amount of water activity of each of the manufactured products was evaluated using a water activity measuring device (at a temperature of 25 degrees Celsius).

Oil: Measuring the amount of oil in donut samples according to the standardAACC2000 No. 30-10 was done [8].

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Specific volume and porosity: To measure the specific volume of donut samples from the volume replacement method with rapeseed according to the standardAACC, 2000 No. 01-08 was used [8].

Porosity: In order to evaluate the porosity of donut samples, the processing technique was used [12]. At first, in order to evaluate the porosity, a 25 mm sample piece was separated by a saw knife and images were taken from all three sections using a scanner with a resolution of 600 pixels and available to the software.Image Jwas placed and gray level images were created by enabling the 8-bit part. In order to convert gray images into binary images, the binary part of the software was activated. These images are a collection of light and dark points, and the calculation of the ratio of light to dark points is estimated as an indicator of the porosity of the samples. It is obvious that the higher this ratio is, the higher the amount of holes in the fabric (porosity). In practice, by activating the Analysis part of the software, this ratio was calculated and the porosity percentage of the samples was measured. Finally, the average porosity calculated for all three sections of the sample was reported as the final number of porosity.

Color: Color analysis of each of the products produced byIt was done by determining three indices L*, a*, b*. L* index represents the lightness of the sample and its range is variable from zero (pure black) to 100 (pure white). The a* index shows the closeness of the color of the sample to green and red colors and its range varies from -120 (pure green) to +120 (pure red). b* index shows the closeness of the color of the sample to blue and yellow colors and its range varies from -120 (pure blue) to +120 (pure yellow). In order to measure these indicators, first the images prepared from the samples were provided to the Image J software. Next, by activating the LAB space in the Plugins section,The above characteristics were calculated [13].

Tissue stiffness: Evaluation of the texture of each product usingHistometer device (QTS (CNS Farnell), manufacture England) was done. The maximum force required to penetrate a probe with a cylindrical end (2 cm in diameter and 2.3 cm in height) at a speed of 30 mm per minute was calculated as a hardness index [14]. In addition, the bending test was also used to evaluate the stiffness of the biscuit texture, and the maximum force recorded to bend and break the sample was reported as a stiffness index [15].

Sensory properties: The sensory test was performed using the method suggested by Haglund et al. (1998) [16]. For this purpose, 10 judges were selected from among the trained people and then sensory characteristics such as form and shape, color, taste (taste and aroma) and firmness and softness of the texture of the manufactured products, which were ranked 4, 3, 2 and 1 respectively. , was evaluated by these taste judges. In the end, overall acceptance was obtained from the sum of the evaluation and ranking coefficients. The evaluation coefficient of traits is from very bad (1) to very good (5).

5-2- Statistical plan and results analysis method

The results obtained from this research were evaluated using SPSS version 22 software and in order to investigate the effect of replacing different levels of wheat flour with resistant starch in each of the donut, biscuit and cookie products from a completely random design separately. was used Samples were prepared in three replicates and averages were compared using Duncan's test at a significance level of five percent ($P<0.05$). At the end, to draw graphs using Excel software, Stephwas given

3. Results and Discussion

3-1- Qualitative characteristics of wheat flour and corn starch

The physicochemical characteristics of wheat flour and corn starch used in the preparation of samples are given in Table 1.

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Table 1. Physicochemical properties of wheat flour and corn starch

Physicochemical properties (%)	Wheat flour	Corn starch
Moisture	13.6±0.1	11.2±0.1
Protein	12.3±0.0	0.4±0.0
Fat	1.25±0.10	0.3±0.0
Ash	0.64±0.04	0.12±0.02
Wet gluten	29.7±0.5	-

2-3- Quantitative and qualitative characteristics of meals

3-2-1- Humidity

Table 2 shows the effect of replacing wheat flour with different levels of type 3 resistant starch on the moisture content of biscuits, donuts and cookies during two time periods of 2 hours and 5 days after baking. As can be seen, by substituting the above-mentioned compound in the formulation of the mentioned products, the final moisture level increased in both time periods of 2 hours and 5 days after baking. Of course, the amount of moisture increase in the product is significant only after replacing the level of 20% or more in the product, and in the meantime, according to the type of products under investigation, the highest and lowest amount of moisture was observed in the sample containing 30% resistant starch and the control sample, respectively. became In this regard, it seems that resistant starch has the ability to absorb water and in combination with wheat flour in the formulation, it has strengthened the ability to maintain the moisture of the dough and the product. In this regard, Babu and Primalawali (2017) investigated the effect of replacing resistant starch with wheat flour at 0, 10 and 15% levels on the quality characteristics of bread and stated that the moisture content of the product increased from 27.35 to 83. 29/Receipt [17]. Also, Laguna et al. (2011) investigated the effect of replacing resistant starch with wheat flour at levels of zero, 20, 40 and 60% on different characteristics of dough and biscuit products and stated that biscuits containing resistant starch have more moisture than the control. had They attributed the reason for this to the increase in the moisture retention capacity of dough containing resistant starch [7]. Maqsoodlou et al. (2015) also investigated the effect of third type or retrograde resistant starch fibers at levels of zero, 5, 10, 15, 20, 25 and 30% (based on the weight of flour) on different characteristics of the cake, including moisture level, height, crust color, The color of the core of the cake and the texture were examined and they stated that the cakes containing resistant starch had more moisture in both the first day and the seventh day of storage compared to the control. He cited the high ability of resistant starch fiber to increase water retention capacity as the reason for such phenomena [18].

Table 2. Effect of wheat flour replacement by resistant starch type III on moisture content of biscuit, doughnut and cookie

Resistant starch (%)	Moisture (%) Biscuit 2h after baking	Biscuit 5 days after baking	Doughnut 2h after baking	Doughnut 5 days after baking	Cookie 2h after baking	Cookie 5 days after baking
0 (Blank)	3.75±0.03^{c}	3.67±0.00^{c}	19.02±0.11^{c}	15.43±0.10^{c}	11.08±0.21^{c}	10.59±0.09^{c}
5	3.78±0.01^{c}	3.71±0.05^{c}	19.12±0.08^{c}	15.55±0.12^{c}	12.10±0.11^{c}	10.68±0.14^{c}
10	3.81±0.03^{c}	3.75±0.03^{c}	19.68±0.17^{bc}	15.98±0.10^{bc}	12.17±0.15^{c}	10.73±0.33^{c}
15	3.82±0.02^{c}	3.79±0.00^{c}	19.91±0.25^{b}	16.05±0.05^{bc}	12.35±0.26^{bc}	10.80±0.20^{bc}
20	3.91±0.00^{b}	3.85±0.04^{bc}	20.20±0.07^{a}	16.19±0.14^{b}	12.62±0.34^{b}	11.06±0.11^{abc}

25	4.04 ± 0.06^{ab}	3.92 ± 0.02^{b}	20.29 ± 0.41^{ab}	16.34 ± 0.11^{ab}	12.83 ± 0.17^{ab}	11.25 ± 0.00^{ab}
30	4.13 ± 0.02^{a}	4.01 ± 0.01^{a}	20.42 ± 0.66^{a}	16.95 ± 0.06^{a}	13.07 ± 0.52^{a}	11.42 ± 0.37^{a}

(Means in each column with different letters differ significantly in $p<0.05$)

3-2-2- Aquatic activity

Figure 1 shows the effect of replacing wheat flour with type 3 resistant starch on the amount of water activity of three biscuits, donuts and cookies. As can be seen, by replacing the above-mentioned compound in the formulation of the mentioned products, the amount of final water activity decreased. Of course, the decrease in the water activity of the product is significant only after replacing the level of 20% or more in the product, and in the meantime, according to the type of products under investigation, the lowest and the highest amount of water activity is respectively in the sample containing 30% resistant starch. And the control sample was observed. According to the matters discussed in the moisture evaluation section, it seems that resistant starch has the ability to bind to water, and in combination with wheat flour in the formulation, it prevents the increase of water activity of the product [19]. In this regard, Pourahmadi et al. (2018) investigated the effect of replacing resistant starch with wheat flour at levels of zero, 20, 40, 60, 80 and 100% on the qualitative and textural characteristics of dough and biscuit products and stated that biscuits containing starch Compared to the control, resistant had less water activity. He related the reason for this to the crystalline properties of starch [20]. Also, this can be attributed to the formation of a gel network and the entrapment of water in it, and of course, the reduction of contact with polar water molecules. In this case, the moisture (free water) of the produced food increases and its water activity (bound water) decreases.

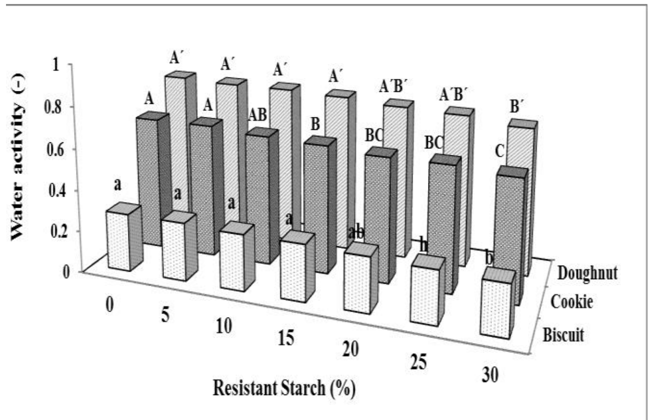

Fig 1. Effect of wheat flour replacement by resistant starch type III on water activity of biscuit, doughnut and cookie

(Means in each product with different letters differ significantly in $p<0.05$)

3-2-3- oil

Figure 2 shows the effect of replacing wheat flour with type 3 resistant starch on the amount of oil in three products: biscuits, donuts and cookies. As it can be seen, by replacing the above-mentioned compound in the formulation of the mentioned products, the amount of final oil was reduced only in donuts. Of course, the amount of oil reduction in the product is significant only after replacing the level of 20% or more in the product, and in the meantime, according to the type of products under investigation, the lowest amount of oil was observed in the donut sample containing 30% resistant starch. During the frying process, the water in the shell of the food evaporates, as the evaporation continues, the water migrates from the center to the shell, and the shell of the food remains moist. When water leaves food in the form of steam, oil fills the empty space; For this reason, the amount of oil absorption has a direct relationship with the moisture content of food; So that parts of the food that have a more severe moisture loss will absorb more oil [21]. It seems that resistant starch has the ability to reduce the amount of oil absorption by donuts during the frying process because it increases the moisture content of donuts. Nouri et al. (2017) also investigated the optimization of the effects of adding Persian gum and beetroot powder on the characteristics of low-fat donuts and stated that the oil absorption of the product decreased with the addition of edible fibers [22]. Also, Brennan et al. (2014) also stated in their review entitled the effect of oil absorption reducing compounds during the frying process that gums prevent the replacement of water with oil during the frying process due to their ability to absorb and retain water [23].

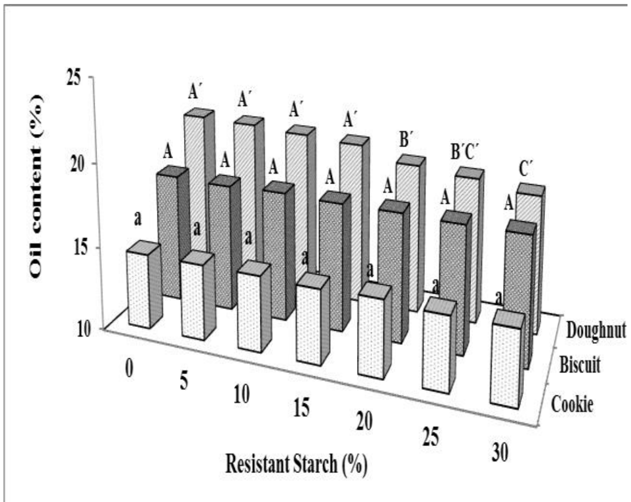

Fig 2. Effect of wheat flour replacement by resistant starch type III on oil content of biscuit, doughnut and cookie

(Means in each product with different letters differ significantly in p<0.05)

3-2-4- Donut specific volume and porosity

Figure 3 shows the effect of replacing wheat flour with different levels of type 3 resistant starch on the specific volume of donuts. As can be seen, by substituting the above-mentioned compound in the donut formulation, the specific volume and porosity of the final product decreased. Of course, the decrease in specific volume and porosity of the product was significant only after replacing the surface by 20% or more in the product, and in the meantime, the lowest amount of these parameters was observed in the sample containing 30% resistant starch.

In general, by adding non-gluten compounds, the rheological characteristics, air retention and porosity of the final product are negatively affected [24]. In this regard, it seems that the addition of resistant starch at higher levels prevents the formation of a complete gluten network, which is one of the most important factors that maintain air bubbles. In this regard, Babu and Primalawali (2017) investigated the effect of replacing resistant starch with wheat flour at zero, 10 and 15% levels on the quality characteristics of bread and stated that the specific volume of the product decreased with the increase of resistant starch [17]. Also, Mohebi et al. (2012) the effect of beta-glucan prebiotics at the rate of 0.8, 1 and 1.2% (w/w) and resistant starch at the rate of 5.5, 8 and 10% (w/w) on quality characteristics and evaluated the sensation of toast. His results showed that the addition of resistant starch decreased the specific volume and the ability to keep air bubbles in the final product. He attributed the reason for this to the tolerance of the gelatinization process during cooking by resistant starch and stated that in this state the starch remains in granular form and is not affected by the amylolytic enzymes of the yeasts, and in the fermentation process, the yeasts have the ability to break down and use it. They don't have [25].

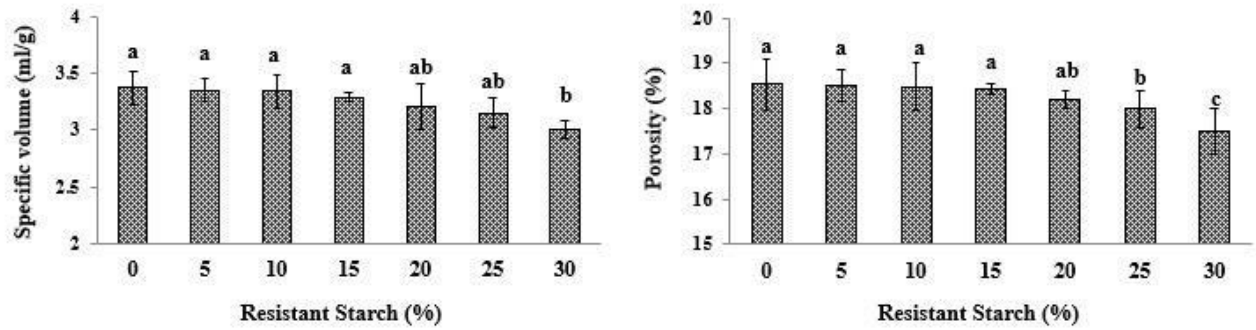

Fig 3. Effect of wheat flour replacement by resistant starch type III specific volume and porosity of doughnut (RS: Resistant Starch)

(Means with different letters differ significantly in p<0.05)

3-2-5- tissue stiffness

Table 3 shows the effect of replacing wheat flour with type 3 resistant starch on the hardness of three biscuit, donut and cookie products at two time intervals of 2 hours and 3 days after baking. As it can be seen, with the increase in the amount of replacement of the above-mentioned compound in the formulation of the mentioned products in both time periods of 2 hours and 3 days after cooking, the amount of tissue stiffness first decreased and then increased. Of course, the increase in product texture stiffness was observed only after replacing the surface by 20% and more in the examined products. On the other hand, according to the results, it was found that with the passage of time (the third day), the hardness of the product increased. Probably due to the interference of resistant starch in the formation of the gluten network, as well as having a higher specific volume and porosity, as well as higher moisture content (non-significant), the sample containing 15% of resistant starch had a lower degree of stiffness in both time frames of 2 and 72 hours after baking. . In this regard, Pourahmadi et al. (2018) investigated the effect of replacing resistant starch with wheat flour at different levels on the qualitative and textural characteristics of dough and biscuit products and stated that biscuits containing resistant starch have less hardness compared to the control. Was. He attributed the cause of this issue to the delay in the gelatinization of starch granules, followed by the increase in starch gelatinization temperature, which ultimately leads to a decrease in hardness in samples containing resistant starch [20]. Bixoli et al. (2008) also investigated the effect of replacing wheat flour with different levels of resistant starch in fresh muffins. They observed that with the increase of fiber levels, the stiffness of the samples decreased so that the lowest stiffness was related to the highest levels of resistant starch [26].

Table 3. Effect of wheat flour replacement by resistant starch type III on firmness of biscuit, doughnut and cookie

Resistant starch (%)	Firmness (N)					
	Biscuit		Doughnut		Cookie	
	2h after baking	3 days after baking	2h after baking	3 days after baking	2h after baking	3 days after baking
0 (Blank)	124.7 ± 3.2^{b}	129.2 ± 0.6^{a}	25.1 ± 0.4^{b}	31.7 ± 0.2^{b}	48.5 ± 0.1^{a}	55.6 ± 0.1^{a}
5	124.1 ± 1.7^{bc}	128.1 ± 2.0^{ab}	24.9 ± 0.3^{b}	31.6 ± 0.2^{b}	48.1 ± 0.2^{a}	55.5 ± 1.4^{a}

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10	122.4±2.3^{c}	128.5±1.3^{ab}	24.2±0.7^{bc}	30.5±0.3^{c}	47.0±0.5^{ab}	54.4±0.3^{a}
15	119.8±2.6^{d}	125.1±0.9^{c}	22.9±0.5^{c}	28.2±0.4^{d}	46.3±0.6^{b}	52.1±0.0^{b}
20	123.8±1.0^{bc}	126.6±0.4^{b}	23.7±0.3^{bc}	30.5±0.4^{c}	47.1±0.4^{ab}	53.2±1.1^{ab}
25	125.6±2.5^{b}	128.2±1.0^{ab}	24.7±0.4^{b}	31.8±0.1^{b}	47.9±0.0^{a}	54.8±0.9^{a}
30	129.5±2.5^{a}	130.1±1.2^{a}	26.7±0.6^{a}	33.2±0.6^{a}	49.1±1.7^{a}	55.6±1.0^{a}

(Means in each column with different letters differ significantly in $p<0.05$)

3-2-6- Color

Table 4 shows the effect of replacing wheat flour with type 3 resistant starch on the amount of color components of three biscuit, donut and cookie products. As can be seen, by replacing the above-mentioned compound in the formulation of the mentioned products, the amount of L* component increased. Of course, the increase in the L* component of the product was significant only after replacing the level of 15% or more in the product. This was while the amount of a* and b* components was reduced and this reduction was significant at levels above 20% ($P\geq0.05$). According to the evaluation section of the product's moisture level, it seems that resistant starch, due to its ability to retain moisture and its more uniform exit from the product's texture during the cooking process, causes moisture to be transferred slowly and more continuously from the core to the shell, and in The result is a smooth surface with the least amount of wrinkling in the final product, which has been effective in reflecting light and increasing brightness. Changes in the surface of foods are responsible for its brightness, and regular and smooth surfaces have a greater ability to reflect light and increase the amount of L* component than wrinkled surfaces. In this regard, Pourahmadi et al. (2018) investigated the effect of replacing resistant starch with wheat flour on the qualitative and textural characteristics of the dough and biscuit product and stated that the biscuits containing resistant starch had a higher L* component compared to the control. He related the reason for this, on the one hand, to the decrease in the amount of protein in the product with the increase in the amount of resistant starch in the formulation, followed by the decrease in the intensity of the Maillard reaction (one of the factors that cause color), and on the other hand, to the bright color of the resistant starch used [27]. . Majzoubi et al. (2014) also investigated the effect of adding resistant corn starch on the physicochemical characteristics of the cake and their results showed that adding resistant starch at levels of 20 and 30% increased the L* component of the shell and core of the product. He attributed the cause of this issue to the light color of resistant starch [6]. In addition, during the preparation of the products of baking and frying industries, Maillard reactions take place to a large extent. The compounds formed from these reactions are responsible for the color change and also affect the taste and textural characteristics [27]. As can be seen, at the levels of 20% and more, resistant starch substitution in the formulation of the studied products significantly reduced the amount of a* and b* components of the shell and core of the product, and up to the level of 20% of this composition, there was a significant difference Dari was not observed in the mentioned parameters ($P\geq0.05$). In this regard, as stated in the evaluation section of the amount of the L* component, it is likely that increasing the amount of resistant starch in the formulation of the examined products will reduce the amount of gluten (a kind of total protein) in the product, which will reduce the intensity of the Millard reaction, because the said reaction for Amino acid and carbohydrates are needed to be done. In this regard, Majzoubi et al. (2014) also

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investigated the effect of adding resistant corn starch on the physicochemical characteristics of the cake and the results showed that by adding resistant starch at levels of 20 and 30%, the amount of a* and b* components of the shell and core The product decreased. He stated the reason for this issue is that by adding this compound in the formulation, the amount of other compounds participating in the Maillard reaction (sugar and amino acid) and caramelization has been reduced, as a result of which the color of the final product becomes lighter [6].

Table 4. Effect of wheat flour replacement by resistant starch type III on color values of biscuit, doughnut and cookie

Products	Color values (-)	Resistant starch (%)						
		0 (Blank)	5	10	15	20	25	30
Biscuit	L*	53.42±2.12 b	53.45±1.16 b	53.51±1.08 b	54.95±1.10 ab	55.02±2.32 ab	56.45±0.74 a	56.95±1.32 a
	a*	17.54±0.33 a	17.48±0.14 a	17.39±0.75 a	17.28±0.07 a	15.98±0.15 b	15.33±0.33 bc	14.45±0.67 c
	b*	34.65±0.10 a	34.60±0.09 a	34.46±0.22 a	34.28±0.36 a	33.09±1.20 ab	32.27±0.50 b	31.06±0.13 c
Doughnut	L*	40.65±0.37 c	40.85±1.10 c	41.03±0.78 c	42.46±0.56 bc	43.18±1.17 bc	43.87±0.37 b	45.42±0.85 a
	a*	26.31±0.58 a	26.27±0.24 a	26.20±0.33 a	25.96±0.74 a	24.41±0.35 ab	24.03±0.00 b	23.39±0.06 c
	b*	21.72±0.65 a	21.69±0.47 a	21.53±0.33 a	21.38±1.01 a	20.87±0.12 ab	19.23±0.62 b	18.04±0.24 c
Cookie	L*	38.01±0.66 c	38.15±1.54 c	38.53±0.67 c	39.75±1.02 bc	40.44±0.88 b	41.65±0.76 ab	42.12±1.06 a
	a*	23.09±0.30 a	22.99±0.55 a	22.67±0.47 a	22.08±0.34 a	21.37±0.52 ab	19.84±0.20 b	19.12±0.22 c
	b*	24.37±0.05 a	24.33±1.01 a	24.25±0.21 a	24.02±0.19 a	23.02±0.75 ab	22.09±1.16 ab	21.76±0.83 b

(Means in each row with different letters differ significantly in $p<0.05$)

3-2-7- sensory characteristics

The overall acceptance results, which indicate the overall condition of the production samples during the sensory evaluation, showed that by substituting the type three resistant starch composition in the biscuit, donut and cookie formulations, the overall acceptance score of the product increased to the level of 15% of the replacement and in Levels above that decreased. In this regard, Babu and Primalawali (2017) investigated the effect of replacing resistant starch with wheat flour on the quality characteristics of bread and stated that the texture score of the product first increased and then decreased with the increase of resistant starch [17]. In fact, this can be attributed to changes in the texture at high levels of resistant starch, which in this case not only affects the shape, firmness and softness of the texture, which is one of the important sensory characteristics, but also affects The taste of the final product is also effective. Because in textures with different hardness, a different understanding of the intensity of sweetness has been reported [28], which Bland et al. Also, Majzoubi et al. (2014) also investigated the effect of adding resistant corn starch on the physicochemical characteristics of the cake and the results of their sensory evaluation section showed that with the addition of resistant starch at the level of 10%, the texture score of the product was the highest [6]. Also, Majzoubi et al. (2015) investigated the effect of adding barley fiber on the characteristics of dough and sponge cake and the results of their sensory evaluation section showed that adding this fiber at the level of 20% was the highest product texture score [30].

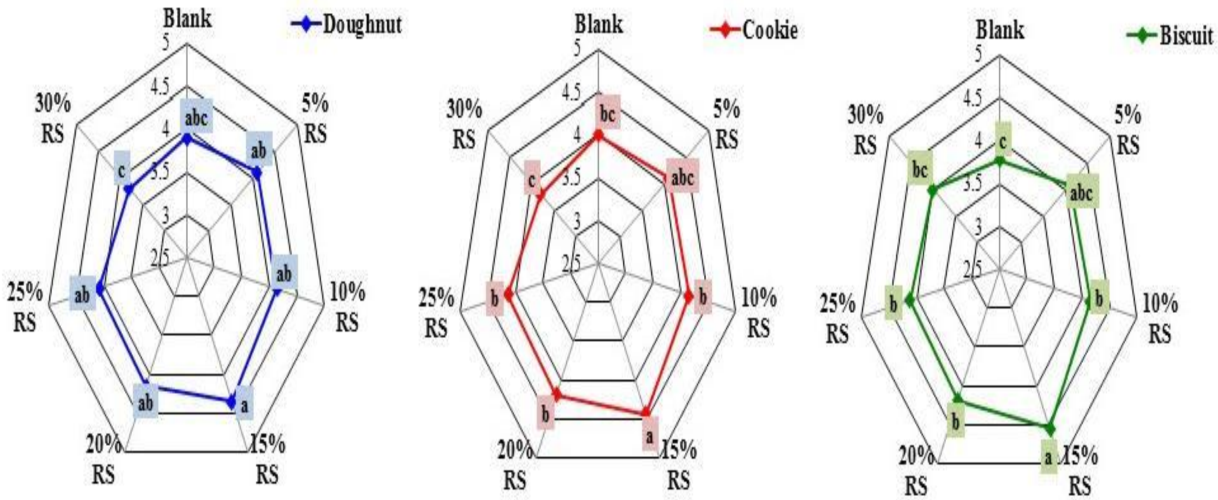

Fig 4. Effect of wheat flour replacement by resistant starch type III on overall acceptance of biscuit, doughnut and cookie

(Means in each product with different letters differ significantly in $p<0.05$)

4- Conclusion

Unlike other dietary fibers, resistant starch improves the quality of food and important functional characteristics in the final product and can easily compete with similar imported samples. This makes food manufacturers use this compound as a valuable supplement in addition to being used in the formulation of grain-based snacks in a wide range of foods. The results of the present research showed that by replacing 15% of wheat flour with resistant starch in the formulation of biscuits, donuts and cookies, in addition to maintaining the physicochemical, textural and sensory characteristics of the final product, it is possible to enrich high-consumption grain-based snacks. exists and the consumer can benefit from the benefits of using prebiotic products.

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مقاله علمی_پژوهشی

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چکیده

نشاسته‌های مقاوم در دسته نشاسته‌های غیرقابل هضم طبقه‌بندی شده و تحت عنوان محصولی پری-بیوتیک معرفی می‌گردد که در مقایسه با سایر فیبرهای رژیمی کالری پائین‌تر داشته و ارزان‌تر می‌باشد. از این‌رو هدف از انجام این تحقیق بررسی تأثیر استفاده از نشاسته مقاوم نوع سه تولید شده به روش حرارتی در سطوح صفر، ۵، ۱۰، ۱۵، ۲۰، ۲۵ و ۳۰ درصد در یک طرح کاملاً تصادفی به عنوان جایگزین آرد گندم در فرمولاسیون بیسکوئیت، دونات و کلوچه بر خصوصیات فیزیکوشیمیایی، بافتی و حسی محصول نهایی بود. نتایج نشان داد با جایگزینی آرد گندم با نشاسته مقاوم در سطوح مصرفی بیش از ۲۰ درصد میزان رطوبت و فعالیت آبی بیسکوئیت، دونات و کلوچه به ترتیب افزایش و کاهش یافت. حجم مخصوص و تخلخل نمونه‌های دونات تولیدی نیز تا سطح ۱۵ درصد نشاسته مقاوم، ثابت و پس از آن روند کاهشی داشت. همچنین نمونه حاوی ۱۵ درصد نشاسته مقاوم در این محصولات از کمترین میزان سفتی بافت برخوردار بود. از سوی دیگر با جایگزینی نشاسته مقاوم در فرمولاسیون بیسکوئیت، دونات و کلوچه تنها در سطوح ۱۵ درصد جایگزینی و بالاتر، میزان مؤلفه L^* افزایش و مؤلفه‌های a^* و b^* پوسته محصول نهایی کاهش یافت. داوران چشایی نیز با بررسی نمونه‌های بیسکوئیت، دونات و کلوچه، نمونه حاوی ۱۵ درصد نشاسته مقاوم را به‌عنوان بهترین نمونه معرفی نمودند. لذا با توجه به نتایج بدست آمده از پژوهش حاضر می‌توان بیان داشت با جایگزین نمودن ۱۵ درصد از آرد گندم با نشاسته مقاوم در هر سه محصول علاوه بر حفظ خصوصیات فیزیکوشیمیایی، بافتی و حسی محصول نهایی، امکان غنی‌سازی این میان وعده‌های غذایی وجود داشته و مصرف‌کننده می‌تواند از مزایای محصولات پری‌بیوتیکی در رژیم غذایی خود بهره‌مند گردد.