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Properties of donuts enhanced by gum and apple pomace powder for development of low-fat fried food

Joelyna, F.A., *Filardli, A.M.I., Prayoga, A., Syafira, F., Abdurahman, A.U., Purwati, D. and Hadiyanto, H.

Department of Chemical Engineering, Faculty of Engineering, Diponegoro University, Semarang, Indonesia

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Abstract

The development of low-fat donuts with the addition of gum (guar gum and arabic gum) and apple pomace powder was carried out in this study. The purpose of this study was to improve the nutritional content of the donuts, especially in reducing the fat content of the donuts by using gum and adding apple pomace powder. The variables in this study were the composition of gum as an ingredient for donuts and the addition of apple pomace powder. Analysis of the dough and donuts characteristics, as well as the donuts appearance and nutritional content, was carried out. Analysis of the donuts texture profile, such as the hardness, and springiness, increased when the composition of apple pomace powder was increased. The proximate composition of donuts (% water, ash, fat, protein and carbohydrates) was analyzed, and there was reduction of fat in the donuts. This study established that adding gum (guar gum and arabic gum) and apple pomace powder can improve the properties of the donuts. Overall, there are significant differences in consumer acceptance, especially in texture and crumb color.

1. Introduction

The preparation of donuts includes frying, which increases their fat content. Although this food is less healthy, donuts are Indonesia's most popular food because almost all age groups can consume them anytime and anywhere. Most consumers have been demanding healthier fried foods for decades while maintaining quality sensory characteristics (Ghaitaranpour *et al*., 2018a; Al Faruq *et al*., 2022). Henceforth, the health food industry is expected to grow by increasing awareness of healthy eating options, including low-fat fried foods. The reduction in residual fat in fried foods and the subsequently developed formulations are widely studied, often with ingredient modifications (Dehghannya and Ngadi, 2021; Al Faruq *et al*., 2022).

Research on donut cooking methods or materials, and ingredients, i.e., in the frying process has been attempted by several researchers (Lee *et al*., 2012; Melito and Farkas, 2013; Ghaitaranpour *et al*., 2018b; Ghaitaranpour *et al*., 2020; Akissoé *et al*., 2021). In terms of composition, adding hydrocolloids to food products reduces their fat content (Choy *et al*., 2012). Therefore, it is possible to develop low-fat donut products with the addition of gum. Gums are a group of polysaccharides commonly used in the food industry for various applications, including viscosity enhancement, texture enhancement, foam and emulsion stabilization, film formation and coating purposes (Dabestani *et al*., 2018). Several types of gums include guar, Persian and Arabic gum.

Nouri *et al*. (2017) used Persian gum and carrot pomace powder to reduce donuts' fat content, however, adding carrots made the donuts' taste and color less attractive. Adding guar gum to bread makes the dough more resilient and gives the dough higher durability, a drier appearance and a softer texture. Besides, adding 1% guar gum to donuts and bread dough can inhibit oil and fat penetration (Mudgil *et al*., 2011). Any other gum, such as Arabic gum, has good adhesive properties and provides smoothness when used as an emulsion stabilizer. The hydrophilic and hydrocolloid properties of the gum can also make bread last longer (Montonegoro *et al*., 2012; Nakov *et al*., 2020).

Previous studies have demonstrated the use of gum in donut formulations, alone or in combination with other additives (Zolfaghari *et al*., 2012; Sabbaghi, 2021; Akesowan *et al*., 2022). To date, there have been more than 100 studies and patents related to donut making. However, to the best of our knowledge, no study has

*Corresponding author.
Email: *amif@students.undip.ac.id*

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combined gum and apple pomace powder as an ingredient for preparing low-fat donuts. Apple is a fruit rich in soluble dietary fiber that can increase water and oil holding capacity, is gel-forming, and stabilizes food with a high-fat content (Nakov *et al*., 2020).

This research aimed to develop food products, notably donuts, which are low in fat and to investigate the effects of gums and apple pomace powder in addition to the swelling power, solubility, baking expansion, and the donut's appearance and nutritional content. Therefore, a standard operational procedure for making low-fat donuts was optimized.

2. Materials and methods

2.1 Materials

The materials used in this study include wheat flour, eggs, sugar, nonfat dry milk powder, vegetable oil and apples from the local market in Semarang, Indonesia. Vanilla extract (Koepoe Koepoe), food-grade Arabic gum (AG), food-grade guar gum (GG), yeast (Fermipan), and baking powder (Koepoe Koepoe) were used for preparing donut from the local market in Semarang, Indonesia.

2.2 Preparation of control donuts

The donuts were prepared using the procedure by Nouri *et al.* (2017), which included mixing 6.3 g of sugar, 1.6 g of salt, 6.3 g of nonfat dry milk and 9 g of shortening. Yeast (3 g) and water were mixed separately and allowed to rest for 5 minutes. Water and eggs (13 g) were added to the bowl containing the shortening mixture. A 1.6 g of vanilla extract was added and blended. In a separate bowl, 100 g of wheat flour was mixed with 1.6 g of baking powder and added to the other ingredients until moistened. Afterward, the yeast mixture was poured into the bowl. The mixture was kneaded to form a dough. The dough was rolled and cut into donut shapes and was rested at 27°C until further analysis.

2.3 Preparation of apple pomace powder

The apples were washed and pressed with a juice extractor and the resulting pomace was collected. The collected fraction was boiled in water (80°C for 3 minutes) and cooled (4°C). The pomace water was filtered with a thin cloth before drying. Next, the apple pomace was dried in the oven (60°C for 12 hrs). The dry pomace was ground to a fine powder using a Moulinex coffee grinder. The apple pomace powder (APP) was filtered at 100 mesh, packed in polyethylene packaging, and stored.

2.4 Preparation of modified donuts

The preparation of modified donuts was carried out in the same way as control donuts. However, it was mixed with gum (guar or Arabic) and different concentrations of APP (Table 1).

2.5 Donuts characterization and quality test

This study tested the dough and donuts produced for physical properties. The swelling power was tested using Leach *et al.* (1959) method, and solubility was tested using a method developed by Kainuma *et al.* (1967). In the texture profile analysis test, the values that describe the texture profile of the material in the form of hardness (hardness), adhesiveness (adhesiveness), springiness (elasticity) and cohesiveness were obtained from the texture profile analysis (TPA) curve. The color testing was performed using the AMT-501 Colorimeter. A colorimeter sensor was applied to each sample; then, the display on the colorimeter display showed a value containing the brightness (L^*), red/green (a^*) and yellow/blue (b^*) values.

A proximate analysis was carried out to determine the nutritional content of the donuts. The proximate analysis consisted of an analysis of moisture content using the oven method (AOAC, 1995), an analysis of ash content using the furnace method (AOAC, 1995), protein content using the Kjeldahl method (AOAC, 1995), fat content using the Soxhlet method (AOAC, 1995), and carbohydrate analysis using the by-difference method (AOAC, 1995).

Table 1. Independent variables and observed values of dough and donut characteristic.

Trial	Independent Variables			Responses						
				Dough Characteristic		Donuts Texture Profile		Donuts Crumb Color		
	GG (g/100 g)	AG (g/100 g)	APP (g/100 g)	Swelling Power (g/g)	Solubility (%)	Hardness (g)	Springiness (mm)	L*	a*	b*
1	0	0	0	8.46	0.0718	781.8	6.8	62.40	2.38	27.12
2	1.2	0	5	9.00	0.0711	413.8	6.3	54.55	4.88	29.37
3	1.2	0	6	8.60	0.0721	186.8	6.4	54.08	3.36	24.51
4	1.2	0	7	7.89	0.0750	256.3	5.7	56.66	5.94	31.42
5	0	1.2	5	8.79	0.0667	281.5	8.5	56.22	5.62	32.42
6	0	1.2	6	8.00	0.0750	543.3	8.5	59.64	7.34	34.33
7	0	1.2	7	7.92	0.0788	354.0	8.3	61.19	5.70	33.90

The control and modified donuts were compared and scored according to their appearance, color, aroma, texture and taste. The overall acceptance is based on a seven-point hedonic scale. The score scale ranges from "very much disliked" (score 1) to "very much liked" (score 7). Thirty panelists organoleptically tested the resulting donuts.

3. Results and discussion

3.1 Dough and donut characteristics

3.1.1 Dough swelling power

The swelling power value of the variable dough was higher or lower than the control dough. The decrease in the swelling power value was caused by the higher amylose content in the donuts (Rahma *et al*., 2017). With the addition of APP, the amylose content increased and exceeded the amylose dissolving capacity in water, even though the amylose already increased due to the binding of the gum. According to Kuakpetoon and Wang (2006), increasing amylose content resulted in less paste formation and reduced swelling power value. Debet and Gidley (2007) and Démé *et al*. (2015) proposed some explanations of swelling kinetics regardless of the amylose content. They evidenced the role of amylose changing the granule envelope structure on the swelling behavior.

The study's results also showed an increase in the swelling power value. A possible explanation is the ability of gums to have good hydration and water-binding properties (Saha *et al*., 2017; Khezerlou *et al*., 2021). Gum increases water hydration by starch granules to reduce the compactness of starch granules. This was also reported by Yu (2010), wherein the swelling power can not only be influenced by amylose content in starch but is also related to amylopectin content, starch granule structure and distribution of starch granules.

3.1.2 Dough solubility

Overall, there was an increase in the solubility with the addition of gum. With the increase in temperature, the oxidation process causes amylose depolymerization, which has a shorter chain length, so it will dissolve readily in water, adding significant solubility value (Moad, 2011). The higher the amylose in apples, the higher the depolymerization and the solubility value.

However, some variables have a smaller solubility value due to the slight influence of gum. Gum chemically consists of two fractions. Although insoluble in water, one fraction can swell and form a gel. Another small fraction is soluble in water to give a colloidal, hydrosol solution (Raoufi *et al*., 2019).

3.1.3 Donuts texture profile

The hardness value is the force required to press the donut to reach 50% of its original height. For donuts, the hardness value should be a manageable size. This is to avoid soft or too-hard products that become unpleasant to eat.

Based on the research data, it was concluded that there were irregularities in different hardness values. However, all variables added with gum had a reduced hardness than without the addition of gum. This is because gum can bind water, which makes it a good stabilizer. Adding gum in bread making can make the dough more kneaded, increase the yield, and give the dough greater durability, a drier appearance and a softer texture. An organoleptic test confirmed this statement.

The smaller hardness value in the variable added with gum is in agreement with the research of Yildiz and Bulut (2015), who reported that the hardness of the cake decreased with the addition of water. This is also following Hendrasty's (2013) report that the amount of water used will provide the desired product quality and is optimized as an intermediate product (dough, batter and paste) which will determine the nature of the final product.

The springiness value describes the product's ability to return to its initial position after the first compression until the second compression begins. The springiness of the formulation donuts for adding GG was lower than that of the control donuts (Table 1). However, with the addition of AG, it had a higher springiness value than the control donuts.

Adding gum produces donuts with a high level of springiness. However, this study also included the addition of fiber from APP. The content of these ingredients significantly affected the specific gravity of the donuts due to variations in water absorption in the ingredients during the stirring and frying process. So that it affects the springiness value of donuts, where the higher the use of the APP, the less the springiness value of donuts. These findings agree with the results of research by Haliza *et al.* (2012) that the fiber composition in Banten taro flour reduces the springiness value of taro brownies. In addition, the results obtained are similar to those mentioned by Singh *et al.* (2012), that springiness is significantly reduced by adding dietary fiber from corn barn by 10% or more in manufacturing butter cake.

Although adding fiber reduces the springiness value of the donuts, the effects caused by AG tend to be greater and increase the springiness value. Its high-density gel-forming properties allow the donuts to return to their

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initial position after the first compression. The difference in effects observed in GG and AG in structure and composition can be seen by Ahmad *et al*. (2019).

3.1.4 Donuts crumb color

Color is one of the physical factors that affect the level of preference of the panelists. The smaller the L value, the darker the color of the donut. Overall, the L value of the donut prepared with gum and APP decreased. The decrease in brightness value is influenced by the caramelization process of glucose, especially APP, in the form of non-enzymatic browning caused by heating the sugar beyond its melting point. The frying process is intense at 180°C. These results are consistent with caramelization requiring temperatures above 120°C for glucose degradation (Hurtta *et al*., 2004). Understanding and explaining the behavior of caramelization during baking can be seen in the research results of Lee *et al.* (2022). This caramelization process impacts appearance and aroma, which was tested using organoleptic tests.

The results in Table 1 showed that the donuts prepared had a bright yellow color with a reasonably high brightness level. This will make these donuts acceptable to the community. This statement will be supported by data tested on an organoleptic basis.

3.2 Donuts nutrition study

3.2.1 Water content

Table 2 shows that the water content of the donuts, with the addition of gum and APP, has increased. The nature of the gum can bind water, making the donuts chewy and soft. According to Ahmad *et al*. (2019), gums are a carbohydrate class that is hydrophilic and has many hydroxyl groups to bind water. The water bound to the gum will then form a gel, so the trapped water is difficult to evaporate.

The fiber in the donuts also affects the water content of the donuts. Fiber can bind water; water tightly bound in dietary fiber is difficult to re-evaporate even with drying (Jiang *et al*., 2019; Huang *et al*., 2020). This confirms the results that the more APP, the more water content.

3.2.2 Ash content

The ability of gum to bind water and act as a stabilizer affects the dissolution of minerals resulting in a decrease in the value of the ash content. In addition, while making donuts, the complex chemical structure changes to a simple one with an increase in the solubility of minerals. This is supported by Santoso *et al.* (2006), who suggested that minerals in food can change their chemical structure during processing or due to interactions with other ingredients. Other results showed that the higher the APP, the ash content is higher. This is influenced by the high ash content of the initial raw material in the APP, affecting the final product. The ash content of donuts can also be influenced by adding the ash content of the supporting material (Onipe *et al*., 2019).

3.2.3 Fat content

Oil uptake from relatively large pores is because of water evaporation in fried foods (Dehghannya and Ngadi, 2021). Besides that, oil degradation occurs during frying due to hydrolysis; therefore, mono and diglycerides, glycerol, and free fatty acids are formed from pure triglycerides. Monoglycerides and diglycerides are polar compounds with active surface characteristics, which reduce the interfacial tension and increase the contact between food and cooking oil, thereby increasing oil absorption (Dana and Saguy, 2006).

Analysis of the fat content in the donuts prepared had a decreased fat content. Hydrocolloid properties of the gum influence the decrease in fat content. Gum can thicken the dough and bind water, so the oil from the frying process needs to be absorbed correctly due to the interaction between polar-non-polar solutions. To better understand the process, the oil uptake mechanism of frying oil was reported by Dehghannya and Ngadi (2021) and Al Faruq *et al*. (2022).

Table 2. Proximate composition of donuts.

Trial	Water (%)	Ash (%)	Fat (%)	Protein (%)	Carbohydrate (%)
1	23.6	1.290	25.90	3.770	45.440
2	19.0	1.057	23.54	3.106	53.297
3	20.2	1.171	22.02	3.194	53.415
4	26.2	1.379	22.70	4.773	44.948
5	25.6	1.014	21.78	3.737	47.869
6	26.2	1.113	23.17	NT	49.517
7	26.8	1.279	27.82	NT	44.101

NT: Not tested.

3.2.4 Protein content

There was an increase or decrease in the protein content of donuts after adding gum and APP. As the apple powder increases, the protein value increases, as is the case with the ash content; formulation of the initial raw material will affect the content of the final product. However, the frying process causes protein loss in making donuts as heat destabilizes hydrogen bonds and non-polar hydrophobic interactions. The high temperatures can increase the kinetic energy and cause the molecules that make up the protein to move or vibrate very quickly, breaking the molecular bonds and causing the protein to be damaged (Bikaki *et al*., 2021).

The ability of gums to hydrate quickly in cold water to achieve very high viscosity is one of the reasons for the decrease in protein content in variable donuts. These properties accelerate the breakdown of proteins into polypeptide chains which are lost due to denaturation.

3.2.5 Carbohydrate content

Carbohydrate content obtained by using gum had more content than the control donut variable. Gum is a polysaccharide that can be categorized as a carbohydrate (Mudgil *et al*., 2011; Montenegro *et al*., 2012; Saha *et al*., 2017; Ahmad *et al*., 2019). The carbohydrate content after the addition of gum will be even greater.

3.3 Consumer acceptance rate

The best donut is determined in community assessment based on the ranking method. Donuts with the highest value are declared the best products (Safriani *et al*., 2013). Table 3 shows the results of the consumer acceptance rate. In terms of texture appearance, there was a significant difference. Although based on the TPA test, the donuts prepared with gum and apple powder showed promising results and were feasible as donuts. However, the infrequent use of gum in donuts in Indonesia makes them chewy and unpopular publicly. There was a significant difference between variables regarding crumb color and texture appearance. Based on the color test, the donuts' color was bright yellow.

Nevertheless, due to the caramelization process, the color becomes slightly brownish, reducing public acceptance of the color effect. Although the aroma and texture of the food ingredients are pleasing, the panelists will only accept the product if the taste is good. In terms of taste, there is no significant difference between the existing variables, and people tend to like the taste and aroma of this donut.

The aroma can determine the delicacy of food products, as well as taste consisting of three components: smell, taste, and mouth stimulation. Aroma is subtle and complex, captured by the senses that combine taste, smell, and stimulation by the tongue. There is a significant difference between the control and variable with gum and apple powder. Trial two had the highest aroma value because GG hydrates APP, thus making the caramelization process faster. As a result of the faster caramelization process, the color of the variable donut will be more brownish, and the aroma will be more fragrant. The best variable based on the organoleptic test was determined from the total organoleptic value. The best variable is trial two (type of GG) and trial seven (type of AG) based on total organoleptic value.

4. Conclusion

Donuts with low-fat content, prepared with the addition of gum (GG and AG) and APP was investigated. Adding gum and APP improved the characteristics and texture of the donuts and the nutritional content (proximate). This study showed that the optimum trial formulation with 1–2 g/100 g AG and 5 g/100 g APP resulted in a low-fat donut with acceptable sensorial properties; therefore, the addition of gum and APP needs to be developed in the future to produce donuts that are not only low-fat but also have better nutritional improvements.

Table 3. Consumer acceptance rate for donuts.

Trial	Sensorial Parameters				
	Texture	Crumb Color	Taste^{ns}	Aroma^{ns}	Overall Acceptance
1	5.63±0.89^{a}	5.60±0.77^{a}	5.27±0.74	5.23±1.01	5.43±0.59^{a}
2	5.83±1.05^{a}	4.87±0.77^{ab}	5.30±0.99	5.70±0.87	5.42±0.82^{a}
3	5.27±1.08^{ab}	4.67±1.15^{b}	5.13±0.97	5.30±1.08	5.09±0.87^{ab}
4	4.77±1.22^{b}	4.33±1.24^{b}	4.73±1.05	5.23±1.04	4.76±0.79^{b}
5	5.40±1.10^{ab}	4.80±0.99^{ab}	5.07±0.87	5.33±1.09	5.15±0.69^{ab}
6	5.13±1.14^{ab}	4.97±0.99^{ab}	4.97±0.93	5.47±0.86	5.13±0.767^{ab}
7	5.60±1.10^{ab}	5.07±1.23^{ab}	5.10±1.21	5.53±0.90	5.32±0.94^{ab}

^{ns}No significant

Values are presented as mean±SD. Values with different superscripts within the same column are statistically significantly different ($p<0.05$).

Conflict of interest

The authors declare no conflict of interest.

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