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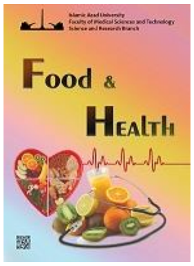

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Optimizing the formulation of functional cookies using oat flour and date liquid sugar (Kaluteh variety) and checking the technological, visual, and sensory properties

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A B S T R A C T

In this research, the variables of oat flour (5, 10, and 15%) and date liquid sugar from Kaluteh dates (10, 20, and 30%) were used instead of wheat flour and sugar, respectively, to reduce energy intake. Cookie properties were investigated, including technological indicators, crust color components, and sensory characteristics. The linear effect of oat flour significantly affected moisture and porosity ($p<0.0001$), while the quadratic effect of date liquid Sugar only affected specific volume ($p<0.05$). The interaction effect showed that moisture and texture first increased and then decreased with higher levels of both variables, while specific volume and porosity showed the opposite trend. The linear effect of oat flour decreased L* and increased a* and b* color components, while the quadratic effect of date liquid Sugar increased a* and b*. The interaction effect significantly increased taste and overall acceptance in the sensory evaluation. The optimal formulations were 7.29% oat flour and 28.710% date liquid Sugar.

1. Introduction

Cookies, a popular snack globally, are traditionally high in calories and low in fiber, made mainly from wheat flour. To enhance their nutritional value, studies have explored the use of alternative flour like buckwheat, barley, or grain flour (1). A cookie is a delightful treat characterized by its nutty sweetness, comprising key ingredients such as wheat flour, oil, sugar, and eggs (2). Functional substances can be utilized as substitutes to reduce fat and sugar content. Additionally, the use of sugar in cookie production can adversely affect its nutritional properties. Replacing sucrose with fermentable and less digestible carbohydrates that act in the small intestine makes it possible to create a valuable and functional product that reduces calorie intake (3). Functional foods encompass those that provide health benefits beyond basic nutrition. These foods can be classified into probiotics, prebiotics, and synbiotics. In the pursuit of producing low-calorie foods, incorporating compounds like plant fibers, known as dietary fiber, has become commonplace. Among the prebiotics, β-glucan is a dietary fiber found in oat bran. Oat bran is fiber-rich and contains β-glucan, although its content is lower than the endosperm. Most of the β-glucan in oat bran is concentrated in the cell wall of the aleurone. Oat bran and its germ contain many minerals and vitamins (4). Cellulose and β-glucan are significant non-starch polysaccharides in oats, making them important dietary fiber in cereal grains. The majority of oat fibers are found in the outer shell. Oats are particularly advantageous compared to other grains due to their high content of this valuable fiber, β-glucan (5, 6). β-glucan is a water-soluble polysaccharide that forms bonds linked by 1,3, 1,4 β-glycosidic bonds. The beta bonds in the structure of β-glucan cannot be broken down by digestive enzymes in the human body, making it a type of water-soluble dietary fiber. When dissolved in water, this polysaccharide creates a highly viscous solution and can lower blood sugar and cholesterol levels. Dietary fibers directly or indirectly affect pancreatic hormones, diabetes mellitus, and fat and sugar metabolism. Water-soluble fibers can directly reduce blood cholesterol concentrations. They also help prevent

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atherosclerosis by increasing levels of high-density lipoprotein (HDL) and decreasing levels of low-density lipoprotein (LDL) (7, 8). A study by Sabet Ghadam et al. (9) found that a cake with 5.163% fiber and 14.9% oil was the best sample on the 8th day of shelf life. Including apple pomace in the cake reduced its fat content by 9.3% compared to the control sample. Despite sucrose's benefits as a natural sweetener with excellent functional properties, its link to health issues such as high blood pressure, heart disease, tooth decay, obesity, and elevated blood glucose levels makes it harmful. Economic and technological factors have also spurred increased research into replacing sugar with alternative sweeteners (10). Choosing the right substitute sweetener and maintaining product quality during storage are crucial to producing sugar-free products. Sugar has multiple functional roles in products, including bulking effects, water stabilization (especially during shelf life), and freezing point control. Dates have a natural sweetness and a distinctively pleasant taste. Date sugar has several advantages over sucrose, such as a lower tendency to crystallize, lower moisture absorption capacity, and higher sweetening power, making it an economical choice for production and consumption. Regarding production cost and raw materials, date-derived liquid sugar can compete favorably in domestic and international markets against sucrose-derived liquid sugar and high-fructose corn syrup (HFCS). As date liquid sugar is made from second and third-grade fruits, it carries significant added value and can strongly compete with similar products like honey (11). In a study investigating date juice containing fructose and sorbitol as a substitute for sucrose in cakes, the sensory evaluation of the cake at different storage intervals revealed that replacing 50% of the sugar with date juice improved taste, texture, and color. However, sensory properties showed a declining trend over time (12). The response surface method was employed in this research to optimize the effects of oat flour and date liquid Sugar on moisture, specific volume, porosity, texture, color components, and sensory characteristics of the cookies. Therefore, this study aims to investigate the impact of substituting flour and sugar with oat flour and date liquid Sugar on the technological properties of functional cookies.

2. Materials and methods

2.1. Materials

For the production of functional cookies in this research, confectionery wheat flour with a low extraction percentage and oat flour was obtained from Golha Manufactory located in Tehran, Iran. These flours were stored in a cold room at a temperature of 4°C to maintain their freshness. Dates, yogurt, solid oil, baking powder, eggs, sugar, and ginger were purchased from a food raw materials and chemical supplier, Merck, based in Germany. The dates used in the study were purchased from the Mashhad market and stored in a cold room above zero degrees Celsius until the start of the experiments. To produce date, liquid Sugar, gelatin, and bentonite were utilized. The gelatin used was type A gelatin, known as Erbigel, with a Bloom number of 100. This gelatin was produced in Germany and used as a 5% solution. Sodium-calcium bentonite, known as Na-Calite, was the type of bentonite used in the research. Both the gelatin and bentonite were obtained from Shahd Iran Company (Mashhad, Iran).

2.2. The extraction of date liquid Sugar

To extract the maximum amount of sugar from the dates, the process began by allowing the desired quantity of dates to reach the laboratory temperature. Once they reached the desired temperature, the dates were cut into smaller pieces to increase the contact surface area with water and expedite the diffusion process. A mixture was prepared by combining the cut dates with 500 grams of distilled water in a 1:4 ratio. To ensure thorough extraction, the water and date mixture was homogenized using a hand mixer at low speed for 2 minutes. The pH of the mixture was then adjusted to around 4 using 5 N citric acid and 1 N sodium hydroxide. The sample beaker containing the mixture was transferred to a water bath set at 77°C and left for 5 hours to facilitate extraction. After the extraction, the beaker was cooled to ambient temperature using cold water. The resulting cooled solution was filtered through a smooth fabric filter to remove any solid particles. Finally, a clarification was conducted to refine and purify the extracted date juice. It is worth mentioning that the juice extraction conditions used in this step were optimized separately, ensuring the extraction was carried out under the optimal conditions determined from previous experiments (13). In the second step of the process, 100 mL of date juice was carefully poured into a 250 mL Erlenmeyer flask. To facilitate clarification, bentonite and gelatin were employed. Before use, the bentonite needed to be soaked in water, so a 20% bentonite solution was prepared 8-12 hours before the experiments. Then, 3 g/L of bentonite, as the 20% solution, was added to the Erlenmeyer flask. Considering the acidic nature of bentonite, the pH of the mixture was slightly reduced. The pH was adjusted to 3.3 using citric acid and sodium hydroxide to achieve this. The date juice and bentonite were stirred for 10 minutes using a magnetic stirrer at a low speed and at ambient temperature to allow the reactions to complete. Subsequently, a gelatin solution was added to the mixture at a rate of 0.05 g/L. After stirring for 10 minutes, the mixture comprising the date juice, bentonite, and gelatin was transferred into a water bath set at different temperatures and held for specified durations. After the treatment, the solution was cooled to ambient temperature using water. The cooled solution was passed through Watman filter paper (No 42) to separate any unsettled phase or impurities from obtaining a clarified juice. The resulting clarified date juice was then ready for use in the formulation of cookies (14).

2.3. Preparation of cookies

First, oil is mixed with powdered sugar (sucrose), and then flour is added to it. After they are well mixed, yogurt, ginger, and baking powder are added. Next, the eggs are beaten lightly in a separate container until combined. The yolk and white should be thoroughly combined. This egg mixture is added to the main ingredients, and the dough is kneaded. The dough is allowed to rest for an hour. At this stage, the dough is opened with a rolling pin on a smooth surface and then molded into shapes using specific molds. The molded dough is arranged on a baking tray lined with oil paper. The oven should be preheated for 15 minutes before baking. The tray containing the prepared cookies is placed in the oven at 150°C. After baking, the cookies are cooled at room temperature. Cookies are produced with variables of oat flour (5, 10, and 15%) instead of wheat flour and date liquid sugar (10, 20 and 30%) instead of sugar. The control sample is prepared separately. The cookies are placed in plastic bags to evaluate their technological and sensory properties. They are stored at ambient temperature (2).

2.4. Moisture

The moisture content of the cookies was measured within 2 hours after baking according to AACC standard method 16-44. An oven (OF-O2G model, Jeto Tech Company, South Korea) set to 100-105°C was used to dry the samples.

2.5. Special volume

The specific volume was determined using the rapeseed displacement method. A 2 x 2 cm sample was taken from the geometric center of each cookie within 2 hours of baking, and its specific volume was measured according to the AACC method (15).

2.6. Porosity

The porosity of the cookie crumb texture was evaluated within 2 hours of baking using image analysis. A 2 x 2 cm crumb sample was scanned (HPScanjet G3010, 300 dpi), and the image was analyzed using ImageJ software to determine porosity (16).

2.7. Texture

Texture was analyzed within 2 hours of baking using a texture analyzer (QTS model). A 2 cm diameter x 2.3 cm high cylindrical probe entered the cookie center at 30 mm/min until reaching 25 mm or 0.05 N force. The maximum force was recorded as the firmness index (17).

2.8. The color of the crust

The color of the cookie crust was analyzed 2 hours after baking by determining L*, a*, and b* values. Images were captured using a scanner (HP Scanjet G3010, 300 dpi) and analyzed in ImageJ software after activating the LAB color space in the Plugins menu (18).

2.9. Sensory properties

A 5-point hedonic scale was used to evaluate sensory characteristics. Ten trained panelists rated the appearance of upper and lower surfaces, texture (firmness, softness, crispness), taste, and overall acceptance. Scores ranged from 1 (lowest) to 5 (highest) for each attribute (19).

2.10. Statistical design

Response surface methodology (RSM) using a face-centered central composite design (FCCD) was applied to determine the effects of independent variables: oat flour (5, 10, 15%) and date liquid sugar (10, 20, 30%). Dependent variables measured were moisture, specific volume, porosity, texture, crust color, and sensory attributes. Data were modeled using Design Expert software. Response surfaces were generated to examine relationships, and numerical optimization identified optimal conditions. A quadratic polynomial model was fitted to the response function (y) representing qualitative and sensory responses.

Eq.1 $$y = b0 + b1x1 + b2x2 + b3x3 + b4x4 + b11x12 + b22x22 + b33\,x32 + b44\,x42 + b12x1x2 + b13x1x3 + b14x1x4 + b23x2x3 + b24x2x4 + b34x3x4 + \varepsilon$$

where, b0, bi, bii, and bij are the regression coefficients representing the intercept, linear, quadratic, and interaction terms, respectively. The model's coefficients are calculated using the least squares method, a multiple regression technique. After obtaining the regression coefficients, the estimated response can be easily calculated using the model relationship. x1 and x2 are the coded levels of the independent variables.

3. Results and discussion

3.1. Effect of variables on moisture

The impact of the independent variables on the moisture content of the cookies is depicted in the response surface plots (Fig. 1). This figure illustrates the influence of oat flour and date liquid Sugar on the variations in the moisture content of the cookies. Based on the coefficients of the independent variables in Eq. (2), it is evident that the relationship between oat flour and cookie moisture is linear, as confirmed by the significance of the model's linear effect ($p<0.0001$).

Eq.2 $$Moisture = +9.37 + 0.233\,A + 0.723\,B - 0.337\,AB + 0.163\,A^2 + 0.313\,B^2$$

The findings indicate a slight increase in moisture content occurs when the quantity of oat flour is increased from approximately 10% to 15%. Inglett and Lee have previously explored similar increases in moisture content and aw values in biscuits and crackers using carbohydrate- and protein-based fat substitutes (20). It's also noteworthy that whole oats were utilized in this study. Cellulose and β-glucan are among the non-starch polysaccharides of oats and are significant dietary fibers in cereals. Most oat fibers are concentrated in its hull. β-glucan, a valuable dietary fiber due to its high quantity, makes oats superior to other grains (5). The addition of dietary fibers to the dough, leading to an increase in the cookie's moisture content, suggesting an increase in dough hydration and the final product (21). The response surface shape suggests a linear relationship between the moisture content and the addition of date liquid Sugar, which is corroborated by the significance of the model's linear effect. The results indicate that as the date liquid sugar increases from 0 to 30%, the cookie's moisture content also increases, resulting in an almost linear increase in the cookie's moisture content. Date liquid Sugar, derived from lower-quality dates, is rich in carbohydrates and dietary fibers. It can be consumed directly or combined with other ingredients in formulating various food items such as bakery products, beverages, and sweets. This has been shown to increase the moisture content of the ingredients used and improve product quality (22). The analysis of variance results for the combined effect of oat flour and date liquid sugar shows that as the amount of oat flour increases, the cookie's moisture content initially increases and then decreases. However, with the addition of date liquid Sugar, the moisture content exhibits a linear decreasing trend, with its optimal value being approximately 10.610. Sugar raises the temperature of starch gelatinization and protein denaturation, which aids in removing moisture from the product. Consequently, reducing sugar in the formulation increases the product's moisture content (23). A sweetener's ability to absorb water is influenced by its size and molecular weight. As the molecular weight of saccharides decreases, their water absorption capacity increases. Most of the sugar in date liquid sugar is reducing monosaccharides (glucose, fructose), with only a small amount of sucrose. Sugars form hydrogen bonds with water molecules through their hydroxyl groups. It seems that due to the structure of sugar molecules, an increase in the functional groups of sugars in date liquid sugar compared to sucrose and the addition of hydrogen bonds leads to an increase in cookie moisture as free water mobility decreases (24).

Table 1. The results of variance analysis of the data related to the characteristics of moisture, specific volume, porosity, and texture firmness.

Source	Moisture			Specific volume			Porosity			Texture		
	Mean Square	F-value	p-value	Mean Square	F-value	p-value	Mean Square	F-value	p-value	Mean Square	F-value	p-value
Model	0.8906	7.83	0.0088	4.19	5.18	0.0263	0.0077	4.01	0.0489	1.52	6.17	0.0167
A- Oat flour	0.3267	2.87	0.1340	1.82	2.25	0.1777	0.0054	2.83	0.1367	0.6667	2.17	0.1436
B-Liquid date sugar	3.14	27.59	0.0012	3.45	4.27	0.0777	0.0204	10.68	0.0137	1.50	6.10	0.0428
AB	0.4566	4.00	0.0855	7.56	9.35	0.0184	0.0020	1.06	0.3375	0.2500	1.02	0.3469
A^2	0.0741	0.6511	0.4463	1.94	2.40	0.1654	0.0034	1.75	0.2271	5.12	20.84	0.0026
B^2	0.2720	2.39	0.1661	3.12	3.86	0.0902	0.0100	5.23	0.0560	1.12	4.57	0.0698
Residual	0.1138			0.8084			0.0019			0.2459		
Lack of Fit	0.1644	2.17	0.2347	0.9693	1.39	0.3670	0.0015	0.6663	0.6153	0.4738	6.32	0.535
Pure Error	0.0759			0.6920			0.0022			0.0750		

3.2. The mutual effect of variables on the specific volume

The impact of independent variables on the specific volume of cookies is depicted in the three-dimensional response surface plots in Fig. 1. Variance analysis of the process variables on specific volume revealed that the squared terms of oat flour and date liquid sugar were significant in the obtained specific volume model. According to the coefficients in Eq. (3), oat flour significantly influences specific volume changes. The linear terms ($p>0.05$) showed a decreasing trend, while the squared term ($p<0.05$) showed a slightly increasing trend. The lack of change in specific volume due to added oat flour can be attributed to the decrease in wheat flour and gluten amounts in the dough with oat flour substitution, reducing the ability to retain gases formed by fermentation. Additionally, air bubbles may not have fully expanded during baking, leading to a heavier cookie with high water absorption and no change or decrease in specific volume in some samples (25). The results of the variance analysis showed that date liquid sugar had a major effect on specific volume changes. The significant squared term ($p<0.05$) confirms this. Specific volume decreased with date liquid sugar content from 0-20% but then increased proportionally as its content rose to 30%. Replacing sugar with even low concentrations of date juice in muffins could increase specific volume by promoting porosity through smaller, more evenly distributed gas cells in the texture. In grain products, specific volume indicates the amount of carbon dioxide and ammonia gases produced from chemical leavening agents used in dough preparation and how they change the kernel structure during baking. Therefore, moisture-absorbing compounds and additives in baking determine specific volume characteristics (26). As oat flour increased, the specific volume of the cookie first decreased, then increased. The amount of date liquid sugar linearly increased the specific volume, with an optimal value of 94.960. Specific volume depends on air bubbles in the dough, their retention during baking, and proper water evaporation. Flour from non-wheat grains lacks gluten, forming a loose dough when mixed with water. Fiber-rich products like date liquid sugar are necessary in mixed formulations when replacing wheat flour with other grain flour like oats. The fiber in these alternatives can store water, increasing dough resistance and cookie texture firmness, positively impacting volume and soft texture. Date liquid sugar plays a significant role in this process (27).

Eq. 3 $$Specific\ volume= +94.80-0.550\ A-0.758\ B-1.370\ AB+0.837\ A^2+1.060\ B^2$$

3.3. The mutual effect of variables on porosity

The effect of variables on cookie porosity is shown in the response surface plots in Fig. 1. Variance analysis showed linear terms of oat flour and date liquid Sugar were significant in the porosity model. Oat flour's linear effect ($p<0.0001$) showed that porosity increased with 0-30% levels. Porosity depends on hole number/distribution - more uniform holes create higher porosity. Therefore, a balanced gluten network improves porosity (28). Date liquid Sugar's only significant effect was linear ($p<0.0001$). Porosity exponentially increased with its levels from 0-30%. Higher porosity seems reasonable, given increased cookie volume results. Faster air bubbles released in sugars' presence could increase porosity (2). The objective was to consolidate repetitive details, focus on key findings and statistical results, and improve clarity and flow between points. The variance analysis showed that the interaction between oat flour and date liquid sugar was insignificant for cookie porosity ($p>0.05$). Porosity initially decreased with higher levels of both variables before increasing, with an optimal value of around 0.425. This aligns with a previous report by Sheikhzadeh et al. (29), which noted decreased donut porosity at high sugar replacement levels with date puree (75-100%) due to the negative impact of puree fibers on dough's gas retention.

Eq. 4 $Porosity= +0.351+0.030\ A+0.022\ B-0.022\ AB-0.034\ A^2-0.602\ B^2$

The mutual effect of variables on texture firmness

The effect of independent variables on the texture firmness of the cookie is shown in the response surface plots (Fig. 1). The analysis results of the process variables on texture parameters indicate that the square effects of date liquid sugar in the obtained model were significant for texture amount. Given the non-significance of oat flour's effect used in cookies ($p>0.05$), it can be inferred that cookie texture is not highly sensitive to changes in oat flour percentage. Some researchers believe staling depends on the physical changes of branched molecules in swollen starch grains. After starch grains swell, some amylose molecules exit the grains and enter the liquid environment. During cooling, these threads connect via hydrogen bonds, precipitate, and provide texture firmness and strength (30). In mixed cookie samples with oat flour, staling is severe in samples with 15% oat flour due to reduced gluten. This facilitates moisture migration from the kernel to the crust, resulting in faster styling and increased firmness. Variance analysis shows that only date liquid sugar significantly affected cookie texture. Sugars inhibit gluten network development, softening cookie texture. In samples with date liquid sugar, crystal formation was either absent or delayed, resulting in softer cookies (31).

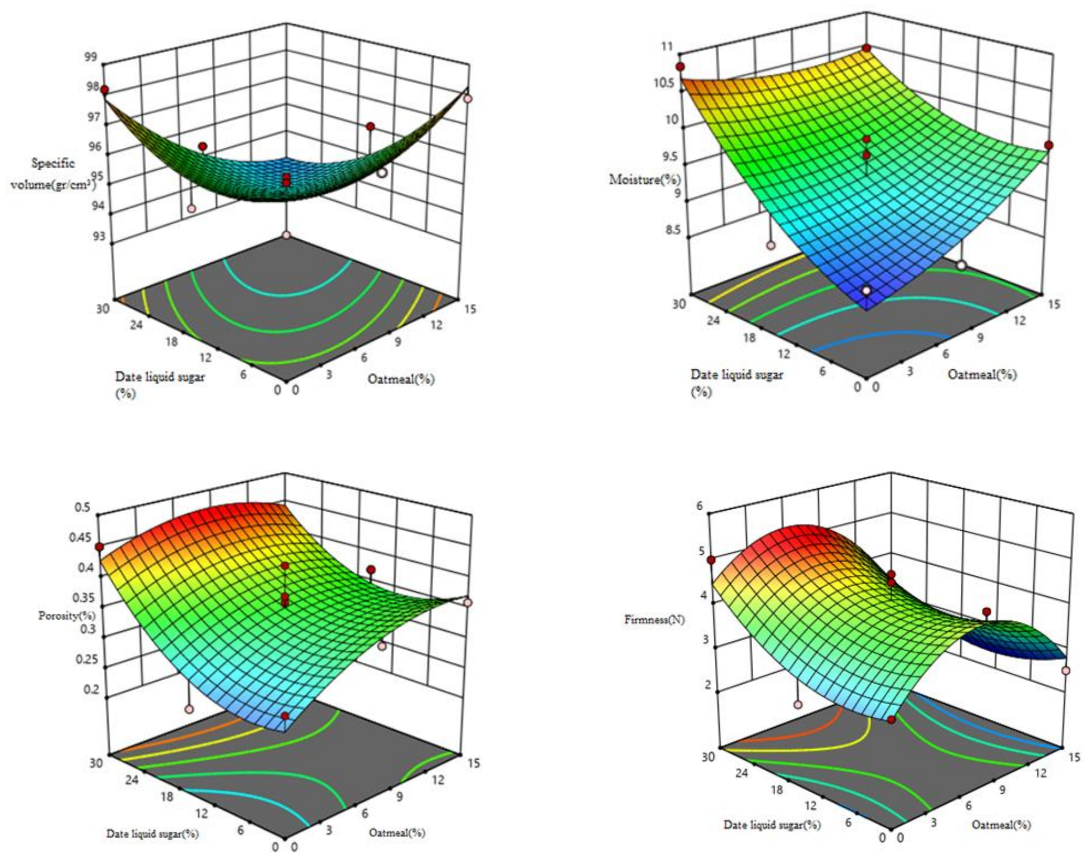

Fig. 1. The effect of oat flour and date liquid sugar on the characteristics of moisture, specific volume, porosity, and texture firmness of cookie.

This could be due to the higher plasticizing properties of fructose and glucose sugars compared to sucrose. As date liquid sugar increased, texture firmness initially increased, then decreased. The increase in oat flour percentage didn't alter product texture firmness. Replacing sucrose with date liquid sugar leads to a decrease in cookie-specific volume and porosity. Increasing date liquid sugar concentration increases moisture content, helping maintain cookie freshness and soft texture. However, oats may reduce product texture quality due to their fiber structure (32, 33).

Eq. 5 $Texture = +4.10 - 0.333\,A + 0.500\,B - 0.250\,AB - 1.360\,A^2 + 0.637\,B^2$

3.4. The mutual effect of variables on colorful components

The impact of independent variables on the color components (L*a*b*) of the cookie is depicted in three-dimensional response surface shapes in Fig. 2. As per the coefficients of the independent variables in Eq. (6), it is evident that oat flour significantly influences the color components. The linear effects ($p>0.05$) show a decreasing trend, while the square ($p<0.05$) indicates an increasing state. Oat flour, being rich in protein, can intensify the Maillard browning reaction and reduce the color component L* (lightness) of the crust. According to Duta and Culetu's reports (34), increasing oat bran in cookies darkens the resulting product and reduces the lightness index. Therefore, besides Millard, the presence of bran in oat flour also increases the color component b* in the produced cookie sample compared to the control sample. The analysis of variance results revealed that among the independent variables affecting the cookie's color components, only the linear effects ($p<0.0001$) of date liquid Sugar were significant in the presented model. The color variance analysis results showed a significant difference between cookie samples regarding two-color components L* and b* (Table 2). The cookie sample with 30% date liquid sugar is darker, while the control sample had the highest lightness (L*). This could be due to fructose, a reducing sugar that participates in the browning reaction, and the amount of color present in dates. On the other hand, the value of the color component b* (yellowness index) is related to the Maillard reaction and pigments in date liquid sugar, which increased with liquid sugar addition compared to the control sample. The analysis of variance results for oat flour and date liquid sugar interaction revealed increased oat flour, the

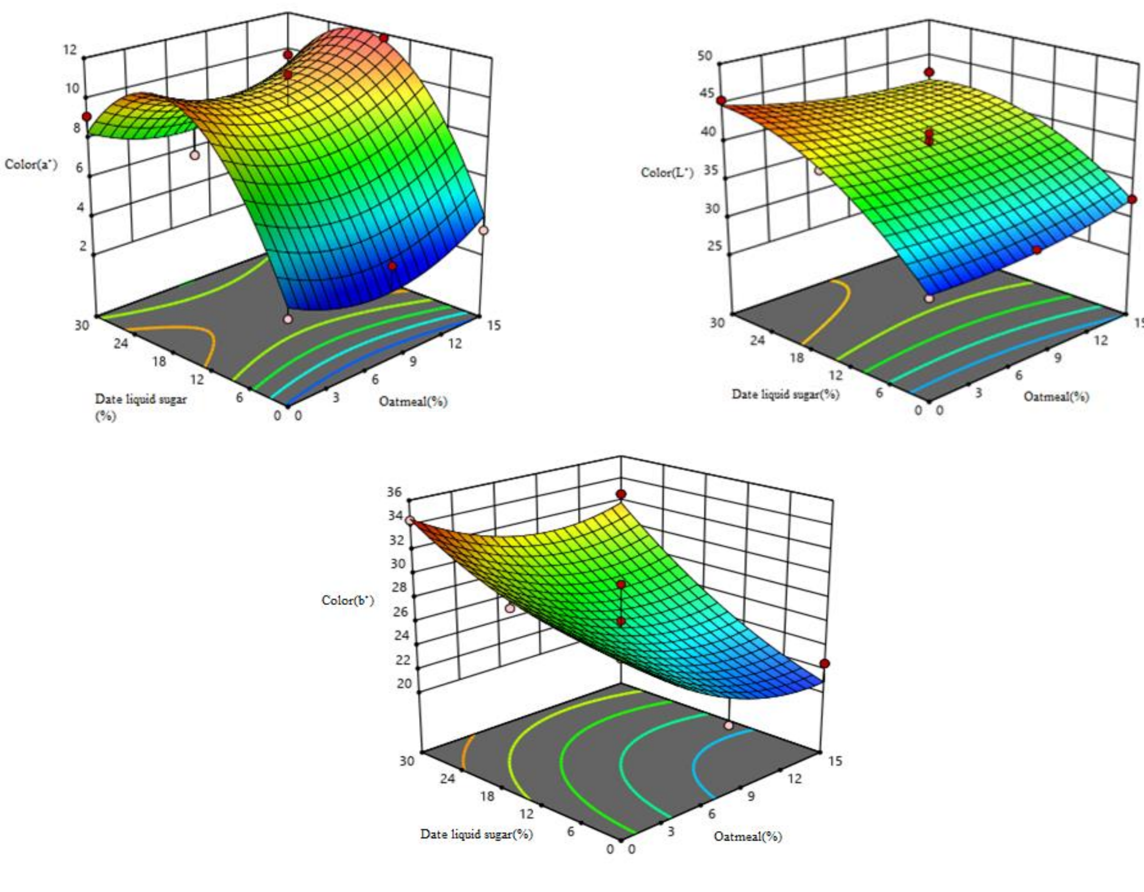

Fig. 2. The effect of oat flour and date liquid sugar on colorful components.

Amount of color component L* (lightness) first increased and then decreased. Increasing date liquid sugar percentage did not change this component amount in produced cookies. Also, with increased independent variables, color components a* and b* first decrease and then show an increasing trend. The optimal values for color component a* were about 9.100, and component b* was approximately equal to 31.910. The interaction effect of these two variables confirmed that the cookie crust's color quality increased with an increase in date liquid sugar. However, color quality showed a nearly downward trend with increased oat flour. This can be attributed to fiber in oats not changing sugar and amino acid amounts. Therefore, changes occurring due to oat flour addition in color components may be due to fiber's buffering role and pH parameter changes resulting in water content changes due to Maillard and caramelization reactions (28). Increasing the replacement of date liquid Sugar in the formulation can intensify browning reactions due to the high amount of reducing sugars glucose and fructose in date liquid Sugar. This can lead to a reduction in the color component L* (lightness) and an increase in the color components a* (redness) and b* (yellowness) (29). As for the crust's color, results indicate that the cookie darkens with an increase in the replacement percentage of date liquid Sugar. This is attributed to the browning reaction near regenerating sugars in date liquid sugar and color substances in date paste. These findings align with the research of Raei et al. (32), and Majzoobi et al. (35). Mansouri Tehrani et al. (36) obtained similar results in their study titled "Production of Date Juice Powder Using Maltodextrin and Its Physicochemical Properties". The study showed that with an increase in maltodextrin amount, the samples' moisture content, bulk density, lightness, and glass transition temperature increased. In contrast, the degree of cakeness of the samples decreased. This is consistent with the results of the present research. Increasing the percentage of date liquid Sugar in the final product formulation makes the produced samples' color darker, which is confirmed by Gómez et al.'s study (37).

Eq. 6 $L\hat{}* = +39.52-0.166\,A+5.980\,B-1.450\,AB+0.989\,A\hat{}2-3.360\,B^2$

Eq. 7 $a\hat{}* = +9.650+0.345\,A+2.470\,B+0.042\,AB+1.660\,A\hat{}2-5.090\,B^2$

Eq. 8 $b\hat{}* = +25.540-2.650\,A+4.150\,B+1.300\,AB+2.190\,A\hat{}2+2.190\,B^2$

Table 2. The results of variance analysis of the data related to the characteristics of colorful components.

Source	L*			a*			b*		
	Mean Square	F-value	p-value	Mean Square	F-value	p-value	Mean Square	F-value	p-value
Model	50.97	36.17	< 0.0001	21.83	17.36	0.0008	36.00	4.60	0.0354
A- Oat flour	0.1667	0.1183	0.7410	0.7142	0.5679	0.4757	42.14	5.38	0.0534
B-Liquid date sugar	214.80	152.42	< 0.0001	36.65	29.15	0.0010	103.33	13.19	0.0084
AB	8.41	5.97	0.0446	0.0072	0.0057	0.9417	6.76	0.8631	0.3838
A^2	2.71	1.92	0.2085	7.62	6.06	0.0434	13.23	1.69	0.2349
B^2	31.19	22.13	0.0022	71.54	56.89	0.0001	4.58	0.5852	0.4693
Residual	1.41			1.26			7.83		
Lack of Fit	2.22	2.78	0.1745	1.93	2.57	0.1921	5.65	0.5972	0.6497
Pure Error	0.8000			0.7520			9.47		

3.5. The mutual effect of variables on sensory characteristics

Fig. 3 illustrates the impact of oat flour and date liquid Sugar on sensory properties such as taste, color, texture, and overall cookie acceptance. According to the coefficients of the independent variables in the proposed models, oat flour did not significantly affect the sensory characteristics of cookies ($p>0.05$). However, an increase in oat flour significantly affected the taste parameter, with linear ($p<0.0001$) and square effects ($p<0.05$). This is because texture firmness increased at higher levels (15%), and specific volume and texture porosity decreased. As per Sandrou and Arvanitoyannis (38), fiber usage in low-calorie food technology can be attributed to the concentration and texture of the aqueous phase in the food system and no change in mouth taste compared to full-fat food. Adding date liquid sugar to the cookie formulation significantly affects texture characteristics, as confirmed by the significance of linear effects ($p<0.0001$) and its square ($p<0.05$). Changing the amount of date liquid Sugar from 0 to 20% did not significantly alter the cookie texture index, but a good improvement in cookie texture was achieved by increasing date liquid Sugar up to 30%. Overall, data review and analysis showed that date liquid sugar positively affected sensory characteristics such as color, taste, and overall cookie acceptance, with an upward trend ($p<0.0001$) observed with its amount increase up to 30%. This is especially true for the texture parameter, as an increase in this independent variable made cookies containing date liquid sugar softer than the control sample. This can be attributed to fructose and glucose sugars' more plasticizer properties than sucrose, which weakened the cookie structure by being placed between starch strands, reducing cookie sample firmness (31). Investigations also revealed that among independent variables affecting taste parameters in cookies, only linear effects ($p<0.0001$) of date liquid Sugar were significant in the presented model. Researchers often consider taste perception and flavoring substance release to depend on the final product's texture type (39). Taylor et al. (40) found that the release time of maximum flavor substances varies with texture firmness. The firmer the texture, the slower the release time of the maximum flavoring material, resulting in a lower score for the sample. Variance analysis results for the interaction between oat flour and date liquid sugar showed that as these two variables increased, the taste parameter first showed a decreasing trend and then an increasing trend. This interaction confirmed that texture quality increased with an increase in date liquid sugar but showed a downward trend with an increase in oat flour. This can be attributed to the strengthening of the sponge network in the cookie with an increase in β-glucan, a non-starch polysaccharide of oat, and an important dietary fiber in cereals (41). Another hypothesis suggests that dietary fibers' effect is caused by two opposite phenomena: an increase in firmness due to reduced swelling of starch and amylose granules and a weakening effect on starch structure due to preventing amylose chain communication. The effect of each factor depends on the type of dietary fiber (42).

Table 3. Results of variance analysis of data related to sensory characteristics.

	Texture			Color			Taste			General acceptance		
Source	Mean Square	F-value	p-value	Mean Square	F-value	p-value	Mean Square	F-value	p-value	Mean Square	F-value	p-value
Model	1.52	6.17	0.0167	1.02	9.27	0.0054	0.3688	2.79	0.1068	0.6659	10.60	0.0036
A- Oat flour	0.6667	2.17	0.1436	0.1667	1.51	0.2586	0.1667	1.26	0.2985	0.3750	5.97	0.0445
B-Liquid date sugar	1.50	6.10	0.0428	2.04	52.18	0.0036	1.04	7.88	0.0263	1.50	23.88	0.0018
AB	0.2500	1.02	0.3469	1.56	14.17	0.0070	0.0000	0.0000	0.0005	0.2500	3.98	0.0862
A^2	5.12	20.84	0.0026	0.7000	6.35	0.0398	0.5985	4.53	0.0709	0.1496	2.38	0.1666
B^2	1.12	4.57	0.0698	0.1774	1.61	0.2452	0.2235	1.69	0.2346	0.6437	10.25	0.0150
Residual	0.2459			0.1103			0.1322			0.0628		
Lack of Fit	0.4738	6.32	0.535	0.1933	4.03	0.1059	0.2084	2.78	0.1743	0.0466	0.6207	0.6377
Pure Error	0.0750			0.0480			0.0750			0.0750		

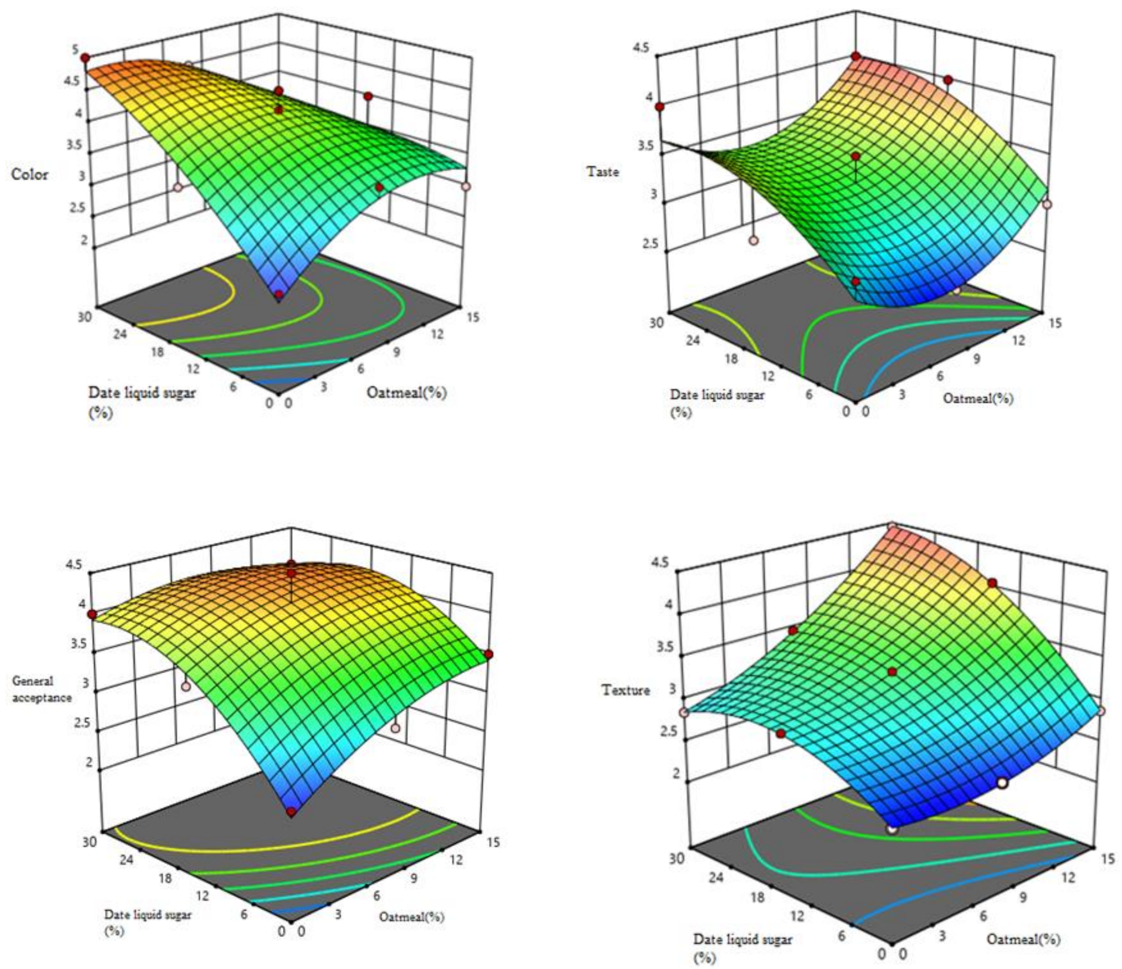

Fig. 3. The effect of oat flour and date liquid sugar on sensory characteristics.

The study found that as oat flour increased, the color amount first increased and then decreased, with its optimal value estimated at 2.93. By increasing date liquid sugar, the color amount showed a linear increasing trend, with its optimal value of nearly 4.43. The decrease in lightness component (L*) and increase in surface tendency towards color components a* (redness) and b* (yellowness) indicate acceleration of browning reaction (Millard) near simple sugars present in date liquid sugar. Therefore, the non-enzymatic browning reaction rate increases due to increased product moisture, leading to darker pigment production. According to the results of the mutual effect of oat flour and date liquid sugar on general cookie acceptance, adding more levels of oat flour (0-15%) and date liquid sugar (0-30%) increased the general acceptance index product. With an increase in oat flour, the general acceptance parameter increased linearly, with its optimal value estimated to be 3.49. Also, by increasing the date liquid sugar amount, product general acceptance increased, with its optimal value being 4.10.

Eq. 9 $Texture= +3.930-0.503\ A+0.549\ B+0.350\ AB-0.273\ A^2+0.736\ B^2$

Eq. 10 $Color= +4.170-0.168\ A+0.584\ B-0.063\ AB-0.503\ A^2-0.254\ B^2$

Eq. 11 $Taste= +3.220+0.167\ A+0.418\ B+0.00005\ AB+0.465\ A^2+0.284\ B^2$

Eq. 12 $General\ acceptance= +4.140+0.250\ A+0.500\ B-0.250\ AB-0.233\ A^2-0.483\ B^2$

3.6. Formulation optimization

To optimize the cookie production formulation, the minimum and maximum values for technological and sensory properties were set equal to the minimum and maximum data obtained from analyzing those properties. Then, target values equaling the data from the sample with the best general acceptance per sensory analysis were considered. The independent variable values for oat flour and date liquid sugar under optimal cookie formulation conditions were 7.291% and 28.710%, respectively. Table 4 lists the corresponding predicted values for all quality attributes achieved with this optimized formulation.

4. Conclusion

Cookies, primarily made from wheat flour, oil, sugar, and eggs, are popular worldwide. However, due to the increasing consumption of snack foods and a growing interest in healthy living, it's important to consider reducing fat and sugar content and incorporating functional ingredients. This research explored replacing wheat flour with oat flour and sugar with date liquid sugar at levels of (5, 10, and 15%) and (10, 20, and 30%) respectively. The study found that adding oat flour initially led to a decrease and then an increase in specific volume and porosity. Conversely, the moisture index decreased with higher oat flour amounts. Increasing date liquid sugar resulted in an increasing trend for measured specific volume and porosity indicators and a decreasing moisture trend two hours after baking. The interaction effect of oat flour and date liquid sugar on cookie texture firmness was also interesting. While there was no effect

Table 4. Cookie sample formulation with optimized properties.

Independent variable	Minimum	Maximum	Optimal value	Response	Quantity
Oat flour (%)	0	15	7.291	Moisture (%)	10.610
Date liquid sugar (%)	0	30	28.710	Specific volume (gr/cm^3)	94.960
				Porosity (%)	0.425
				Texture firmness (N)	4.210
				Colorful component L*	39.750
				Colorful component a*	9.100
				Colorful component b*	31.150
				Texture	2.850
				Color	4.430
				Taste	3.601
				General acceptance	3.950

from the oat flour, a decreasing trend was observed with date liquid sugar. Moreover, both oat flour and date liquid sugar greatly affected the color components of the cookies, reducing the color component L* (lightness) while increasing a* (redness) and b* (yellowness) color components. This improved the sensory properties and general acceptance of the cookies and enhanced the final product's color.

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