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Effect of gum extracts on the bread-making and textural properties of dough and bread made from sour cassava starch (Manihot esculenta), Peanut (Arachis hypogaea) and cowpea flour (Vigna unguiculata)

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A R T I C L E I N F O

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A B S T R A C T

Gluten intolerance, as well as the scarcity of wheat flour in some parts of the world, has prompted the development of gluten-free bread. Gluten-free bread, on the other hand, results in a low specific volume and to remedy this, the use of hydrocolloids and bases has proved to be very successful. The current study aims to determine the optimal proportions of *Triumffeta pentendra* gum extract and bicarbonate in the breadmaking of a composite flour based on sour cassava starch, peanut flour, and cowpea flour. A Box Benkhen design was used to achieved this, with the variables being the amount of gum extract, the amount of bicarbonate, and the amount of water. The specific volume and texture properties were evaluated as responses. The specific volume was calculated using standard methods, and the textural properties were determined using a texture analyzer. It appears that the incorporation of gums extract, bicarbonate, and water significantly increased the specific volume. The incorporation rate of gum extract significantly increases the hardness, consistency, and masticability which decreases with the incorporation rate of bicarbonate and water. Cohesion and elasticity, on the other hand, increased with the incorporation rate of bicarbonate and water but decreased with the incorporation of gum extract. The optimal gum extract, bicarbonate, and water proportions are 0.28 g, 1.99 g, and 112.5 ml, respectively. As a result, the specific volume is 1.51cm3/g, the hardness is 38.51(N), the cohesion is 0.88, the consistency is 32.86 (N), the elasticity is 5.57(1/L), and the masticability is 162.35(mj). According to this findings, gum extracts and sodium bicarbonate can be used to improve the quality of gluten-free bread made with sour cassava starch, peanut and cowpea flour.

1. Introduction

The use of wheat flour alone in bread making causes a number of issues, including gluten intolerance, which affects approximately 1 % of the population (Lebwohl et al., 2018); non-celiac gluten sensitivity (NCGS) (Rotondi Aufiero et al., 2018) and the risks associated with gluten consumption namely : irritable bowel syndrome, digestive disorders, osteoporosis and anaemia (Cenni et al., 2023). On the other hand, wheat flour is deficient in digestible protein and micronutrients (Bonafaccia et al., 2000), In addition to these nutrition issues associated

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with wheat consumption, the scarcity of this item in many nations is jeopardising food safety. In Cameroon, which purchases roughly all of the wheat used on the country's soil, the amount being imported is estimated to be approximately 966,400 tonnes of wheat at an estimated price of about 182.7 billion FCFA. The result not solely in the country's foreign exchange reserves, but also the trade shortage, which is estimated at 1478 billion CFA francs (INS, 2022). Furthermore, the Covid-19 pandemic and the war between Russia and Ukraine caused disruptions in worldwide supply chains and had a lasting impact on livelihoods. (FAO et al., 2022). To address this issue, gluten-free flours have proven to be effective.

Gluten replacement continues to be a significant challenge in the manufacture of bakery products. Is the case in the use of sour cassava starch in bread-making, which results in low-quality bread. Thus, various strategies for enhancing breads based on sour cassava starch have been investigated; the approach consists of optimising post-harvest processing methods to achieve better expansion capacity (Alvarado, 2014) and combining protein sources to improve bread nutritional and technological quality (Cavalcante et al., 2016). As a result, cheese is used in the breadmaking of sour cassava starch (Alvarado, 2014). legumes, due to their high protein content and micronutrient content, may be valued in the production of sour cassava starch breads (Langyan et al., 2022). Among the locally available legumes, peanut, cowpea, and soybean have been widely used in food formulation, with their technological properties in panification demonstrated (Asimah et al., 2016; Founfon, 2021; Ndjang et al., 2021). It is in this context that Ndjang et al. (2023) have demonstrated in their work on the formulation of a bread made from sour cassava starch, peanut and cowpea flour that the incorporation of legumes improves nutritional and technological properties of sour cassava bread. Nevertheless, the addition of protein sources reduces the specific volume of breads, necessitating the use of other ingredients such as hydrocolloids and bicarbonate. In this context, Zapata et al. (2019) demonstrated that the presence of guar gum might modify the textural properties and bread-making ability of sour cassava starch and cheese-based breads. Indeed, hydrocolloids have the ability to modifyd dough rheology and thus improve bakery product quality. They are frequently employed in gluten-free products as gluten alternatives (Kaur et al., 2015). They actually help to improve food texture, water retention, starch retrogradation, and the general quality of the product during storage (Kohajdová & Karovičová, 2009). Gum extracts can be used in the bread-making of sour starch to enhance the bread texture and volume (Vidaurre-Ruiz et al., 2019). Agar, Alginate, arabic gum, Carboxymethyl cellulose, Hydroxypropyl cellulose, Guar gum, Karaya gum, Karobe gum, Tragacanth gum, and Xanthan gum are the most commonly used gums. However, at the local level, other gums have proven to be very interesting, particularly *Truimfetta pentendra* (Nkui) gums, which have expansion properties due to their high-water absorption capacity, which can be exploited in the improvement of bread-making ability (Fanwa et al., 2023). This is the case in the production of doughnuts made from maize, millet, and sorghum flour, where the gum extract of *Truimfetta pentendra* increases the fluidity of the dough, making it more resistant to stretching and producing doughnuts with an airy crumb and higher specific volume (Saidou, 2012).On the other hand, sodium bicarbonate can interact with the lactic acid in sour cassava starch, releasing carbon dioxide into the dough and enhancing its bread-making ability (Atlidakis et al., 2019). As demonstrated by Xiao et al. (2023), the addition of sodium bicarbonate improved the functional and sensory properties of fermented rice flour-based spaghetti. Thus, adding *Triumfetta pentandra* gum extracts and sodium bicarbonate to a sour cassava starch, peanut, and cowpea flour mixture can improved the bread-making and textural properties of dough and bread. Therefore, the general aim of this work is to improve the textural and breadmaking properties of a gluten-free dough and bread base on sour cassava starch, peanut and cowpea flour by determining the optimal conditions for *Triumfetta pentandra* gum extracts and sodium bicarbonate addition.

2. Materials and methods

2.1. Materials

Peanut and cowpea seeds were collected at the local market in Dschang, cassava tubers were collected at a farmer's field in Bertoua and *triumfetta pentendra* stems at a farmer's field in Dschang. The baking ingredients were the composite flour, water, salt, bicarbonate and gum extract. SOCAPURSEL (Douala, Cameroon) provided the salt (white Diamant), which was purchased at a local supermarket as well as bicarbonate.

2.2. Sampling

In a traditional production unit (*Société coopérative simplifiée des transformations de manioc* (SCSTM), cassava starch was wet-extracted. The cleaned and peeled cassava tubers were ground into a fine paste using a rotating and coordinated grinding process known as rapping. The fine paste was then passed through a centrifugal sieve for separation. The starch milk was transferred to sedimentation tanks. The extracted starch was fermented for 30 days, and exposed to light rays for approximately 24 h as described by Alvarado et al. (2013). The cowpea grains were soaked for 12 h, then dried in an oven at 45 °C for about 24 h before being ground and sieved (160 μm) as described by Ndjang et al. (2021). To obtain peanut flour, the protocol described by Salve and Arya (2020) was used; briefly, groundnut seeds were roasted at 150 °C for about 10 min and then ground into flour. The method described by Ndjouenkeu (1995) was used to obtain *Truimfetta pentendra* gum extract: In brief, *Truimfetta pentendra* bark was macerated and stirred at 50 °C, and the resulting extract was dried at 50 °C.

2.3. Response surface methodology

The Box Benkhen design was used to obtain the optimal incorporation rate of gums and bicarbonate for bread formulation. The factors chosen were the amount of gums extrac (A):0,1–1 g, bicarbonate (B):0,2–2 g and water (C):75–150 ml. The responses were the specific volume and textural properties (hardness, cohesion, consistency, elasticity and masticability). The lower and upper limits were determined based on the literature review and preliminary tests. As a result of all analyses, the best conditions for bread production was determined. A Three-variable polynomial model, of the following form, represents the fitted response values:

$$Y = b0 + b1A + b2B + b3C + b1.2AB + b1.3AC + b2.3BC + b1.1A^2 + b2.2B^2 + b3.3C^2 \quad (1)$$

Where Y is the expected response;

b0 the constant
b1 and b2 are the linear coefficients
b1.1 and b2.2 square coefficients
b1.2 interaction coefficient

2.4. Model validation

Model suitability is assessed using six indices. A p-value less than 0.05 which indicates that the factors or their interactions have an important effect on the response. The R^2 which indicates whether the model is suitable or not, must be within the 75–1 % range and the closer it is to one, the more suitable the model. All variations around the model mean are calculated using the adjusted R^2 (R^2 Adj). The predicted R^2 (R^2 Pred) is used to estimate the accuracy with which the model predicts the response value. The predicted residual error sum of squares (PRESS) is used to assess the model's suitability; the smaller it is, the better the model is. In addition, the p-value of the lack of fit should not be significant (Liu et al., 2021).

2.5. Bread-making and responses evaluation

2.5.1. Bread-making

The bread was made in accordance with the protocol described by Alvarado (2014) and modified by Ndjang et al. (2023). Briefly the composite flour (64.11 %, 18.92 %, and 16.96 % of sour cassava starch, peanut and cowpea flour respectively) was mixed with salt (0.5 g/100 g) and water (75–150 ml depending on the expériment) at low speed (165 rpm) for 1 min and then at medium speed (300 rpm) for 2 min in a mixer (Kenwood HMP32 electric hand mixer- United Kingdom (UK)). The dough was shaped (around 300 g), and the dough pieces of 100 g each were baked for 30 min at 250 °C in a baking tray oven (Automatic Range Cooker - EUROLUX-Trendy Inox - 60×90 - 5 Burners - Oven and Gas Bottle Holder- Germany).

2.5.2. Specific volume

The displacement method developed by AACC (2001) was used to determine the volume of the bread. And the specific volume was obtain by dividing the volume of the pain by its mass.

2.5.3. Textural profil

A texture analyzer (Universal Texture Machine, LR 5 K, Lloyd Instruments Ltd., Bognore Regis, UK) equipped with an 80 mm diameter cylindrical probe was used to perform texture profile analysis (TPA) on bread. TPA was carried out in two steps (speed 50 mm/min; compression 50 %; load 1 KN). Using Nexygen software 4.1 (Lloyd material testing, West Sussex, UK), the obtained profile was used to calculate hardness, cohesion, consistency, elasticity, and masticability Shobharani et al. (2015). Hardness is measured in Newton (N) and represents the maximum force obtained during the initial deformation or bite; Cohesion is the ratio of area 2 at the second deformation or bite to area 1 at the first deformation; Elasticity (1/L) is the distance a material takes to return to its original shape after being deformed by a sensor rod. It represents the force that connects the molecules or particles in a bread sample; Gumminess (N) or consistency is a combination of hardness and cohesion, while masticability (mJ) is a measure of gumminess and elasticity. It demonstrates the product's ability to form a food bowl suitable for tasting. The analyses were carried out in triplicate, with mean values calculated.

2.6. Multiple optimizations of the responses

The following conditions were used to optimise the different responses: the specific volume, cohesion, and elasticity were maximised, while the hardness, consistency, and masticability were minimised. The optimal formulation was chosen after a compromise was reached between the various optimal conditions obtained for each response.

2.7. Comparative study of the optimal formulation with the control formulation (SPC)

The control formulation is that developed by Ndjang et al. (2023), which contains 64.11 g/100 g of sour cassava starch, 18.92 g/100 g of peanut powder, and 16.96 g/100 g of cowpea flour, respectively. Since we want to improve this formulation, we used it as our control in this study and we have named it SPC (Starch-peanut-cowpea). To that end, we compared Pasting, sensory, and colour properties, of the SPC's and the optimal flour and bread.

2.7.1. Pasting properties

The pasting properties was analysed according to Sánchez et al. (2009), where the viscous behaviour of the flour was measured using a Rapid Visco Analyzer model RVA-4 Series (Newport Scientific, Warriewood, Australia). In 22.5 g water, 2.5 g flour (dry basis) was dispersed. The following temperature profile was used for the measurement of the viscosity: holding at 50 °C for 1 min, heating from 50 °C to 90 °C at 6 °C. min-1, holding at 90 °C for 5 min, and then cooling down to 50 °C at 6 °C.min-1, with continuous stirring at 960 rpm for 10 s, then at 160 rpm for the remainder of the experiment. Peak viscosity, minimum viscosity (MV), breakdown (BD), final viscosity (FV), setback (SB), peak time (PT), and pasting temperature (PTC) were obtained from the visco-amylogram. The analyses were carried out in triplicate, with mean values calculated.

2.7.2. Sensory analysis

The method described by Koppel (2014) was used for conducting the hedonic test. Each of the bread samples were brought to the participants (60 naive testers) at the same time, and they were requested to fill out a survey indicating their appreciation of the bread on a score of 1 (extremely unpleasant) to 9 (extremely pleasant) for the various descriptors (appearance, odour, texture, taste, crispness). The general level of acceptance was calculated by averaging the various descriptors.

2.7.3. Determination of bread color parameters

Bread colour was measured with a CR210 chromameter (Minolta France S.A.S Carrières -Sur-Seine) based on the parameters L*, a*, and b* (Himeda et al., 2012). The instrument was calibrated against a light-yellow reference tile. A glass cell containing the flour was placed above the light source and covered with a white dish, and the L*, a* and b* values were recorded. The whiteness index (WI) of the flours was determined using the following equation.

$$\mathbf{WI} = \mathbf{100} - \sqrt{(\mathbf{100} - \mathbf{l})^2 + \mathbf{a}^2 + \mathbf{b}^2}$$

2.8. Data analysis

Design-Expert version 11.0 software was used to generate the mixture trials. Excel version 2013 software was used to express the results of the triplicate analyses as means plus or minus standard deviations, and SPSS version 23 software was used for statistical analysis.

3. Results and discussion

3.1. Experimental matrix

The experimental results are shown in Table 1: specific volume varies from 0.47 to 1.77 and increases with the incorporation of gum extract, bicarbonate, and water; hardness (20 to 96), consistency (12.85 to 69.65), and masticability (67.66 to 356.45) increase with the incorporation of gum extract but decrease with the incorporation of water and bicarbonate; cohesion (0.51 to 0.89) and Elasticity (3.92 to 6.05) increase with the incorporation of water and bicarbonate but decrease with the incorporation of gum extract.

3.2. Mathematical model

In order to select the best model for the experiment, the linear, two-factor interaction (2FI), quadratic, and cubic models were examined and compared. The linear model performed best in terms of consistency, elasticity, and masticability, while the quadratic model performed best in terms of specific volume, hardness, and cohesion. The results show that the models fit for specific volume, hardness, cohesion, elasticity, consistency, and masticability were appropriate. with an R^2 greater than 75 % and no statistically significant lack of fit ($P > 0.05$) which is a measure of a model's inability to represent the data for the experimental region (Gan et al., 2007). As a result, the concentration of these responses explains a significant portion of their variability. According to the ANOVA analysis (table 2), A, B, C, AB, AC, A^2, C^2 have a significant influence on specific volumes; A, C, C^2 have a significant influence on

Table 1
Experimental matrix.

Tests	Factors	Responses							
No	A (g)	B (g)	C (ml)	Spc volume (Cm^3/g)	Hardness (N)	Cohesion	Consistency(N)	Elasticity (1/L)	Masticability (mj)
1	0.55	0.2	150	1.53	30	0.51	20.87	6.05	149.22
2	1	1.1	150	1.60	35	0.60	23.87	5.92	159.22
3	0.55	1.1	112.5	1.63	47	0.83	40.91	5.34	177.90
4	0.1	0.2	112.5	1.25	37.5	0.70	27.30	5.55	190.64
5	0.1	1.1	75	0.47	82	0.84	69.65	4.05	258.94
6	0.55	1.1	112.5	1.63	47	0.83	30.91	5.34	177.90
7	0.55	1.1	112.5	1.63	47	0.83	30.91	5.34	177.90
8	0.1	1.1	150	1.09	20	0.64	12.85	6.89	67.66
9	0.55	2	150	1.8	29.5	0.68	20.49	6.25	136.06
10	0.55	2	75	0.69	73.5	0.89	47.30	4.28	221.64
11	0.55	0.2	75	0.49	85	0.83	43.94	4.08	296.48
12	0.1	2	112.5	1.27	37	0.89	25.76	5.88	167.97
13	1	1.1	75	0.50	96	0.87	57.03	3.92	356.45
14	0.55	1.1	112.5	1.63	47	0.83	30.91	5.34	177.90
15	1	0.2	112.5	1.25	56	0.74	40.03	4.92	190.45
16	0.55	1.1	112.5	1.63	47	0.83	30.91	5.34	177.90
17	1	2	112.5	1.77	50	0.87	36.87	5.05	184.42

where A represents the amount of gum extract; B represents the amount of bicarbonate and C represents the amount of water.

Table 2
Assessment of the adequacy of the mathematical model for different responses.

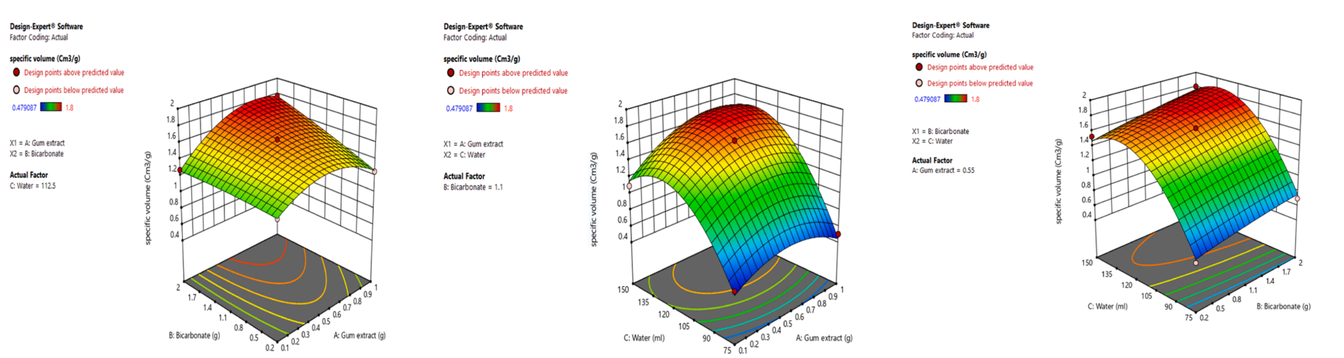
Sources	Spc volume (Cm^3/g)	Hardness(N)	Cohesion	Consistency(N)	Elasticity(1/L)	Masticability (mj)
Model	**< 0.0001**	**< 0.0001**	**< 0.0001**	**0.0001**	**< 0.0001**	**< 0.0001**
A	**0.0004**	**0.0003**	0.6614	0.3062	**0.0002**	**0.0281**
B	**0.0004**	0.0885	**< 0.0001**	0.9355	0.1129	0.1836
C	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**	**< 0.0001**
AB	**0.0032**	0.4331	0.0553			
AC	**0.0036**	0.8841	0.0455			
BC	0.5571	0.1403	**0.0064**			
A^2	**< 0.0001**	0.5790	0.3424			
B^2	0.5181	0.1245	0.0261			
C^2	**< 0.0001**	**0.0004**	**< 0.0001**			

With *A* =gum extract; *B*=bicarbonate; C=water.

hardness; C has a significant influence on consistency; A. C have a significant influence on masticability and elasticity; B. C. AC. BC. B^2. C^2 have a significant influence on cohesion with (P <0.05).

3.3. Effect of factors and response surface analysis components on specific volume

The specific volume is used to express a bread formulation's technological aptitude (Hernández-Aguirre et al., 2019). It is one of the most commonly used technological properties of the bread for determining bread-making ability (Alvarado, 2014). The response surface analysis (Fig. 1) depicts the effect of variables and their interactions on bread specific volume. which appears to increase with the incorporation rate of gum extract, bicarbonate, and water up to the 1.05 g, 2 g, and 142 ml thresholds, respectively. After analysing the data for bread specific volume (Y1) as a function of gum extract (A), bicarbonate (B), and water (C), the following regression equation (Y1) was developed. This demonstrates a positive individual effect of gum extract, bicarbonate, and



a) surface area response of interactions between bicarbonate and gum extract on specific volume

b) surface area response of water/gum extract interactions on specific volume

c) surface area response of water-bicarbonate interactions on specific volume

Fig. 1. Effect of factor interactions on the specific volume.

water, as well as a positive quadratic effect of gum extract, bicarbonate, and water. We also found that gum extract, bicarbonate, and water had a negative exponential effect on the response. This demonstrates that gum extract, bicarbonate, and water have a positive individual effect, as well as a positive quadratic effect. Gum extract, bicarbonate, and water all had a negative exponential effect on the response.

$$\mathbf{Y1} = 1.64 + 0.1281A + 0.1253B + 0.4818C + 0.124AB + 0.1212AC - 0.2301A^2 - 0.488C^2$$

The increase in volume caused by the addition of gum extracts is directly related to the increase in viscosity of the dough, which equaly increases with the addition of gum extracts (Singh et al., 2016). Indeed, the hydrophilic nature of gums results in increased water retention and, consequently increased dough viscosity (Martínez & Pilosof, 2013). As a result in the presence of gum extracts, during the transition of the dough from the fluid to the solid state, there is a greater increase in volume as a result of increased temperature and gelatinization (Gómez et al., 2007). Furthermore, due to the high-water retention capacity of gums, less water is used in the formulation, allowing the dough to grow faster (Martnez & Pilosof, 2013). Another possible explanation is that gum extracts will reinforce the network formed by the starch granules and proteins during baking, resulting in better retention of water vapour bubbles and thus a higher specific volume of the final bread (Vidaurre-Ruiz et al., 2019). However, there is a decrease in specific volume for high incorporations of gum extract. This can be explained by the fact that the amount of hydrocolloid used, the type of flour used, and other ingredients all have an impact on specific volume (Hager & Arendt, 2013).Likewise, the use of locust bean gum and sodium alginate in the formulation of potato-based breads revealed that the amount of hydrocolloid used determined the volume (Horstmann et al., 2018).The increase in volume observed with the addition of sodium bicarbonate, on the other hand, can be attributed to the fact that bicarbonate will interact with the lactic acid present in sour cassava starch and release carbon dioxide into the dough via an acid-base reaction, causing bubbles to expand and thus increasing dough swelling (Atlidakis et al., 2019).

3.4. *Effect of factors and response surface analysis components on hardness, consistency and masticability*

3.4.1. *Hardness*

The highest force intensity when the first compression of the TPA test is reached is defined as hardness (López & Goldner, 2015). A loaf is of higher quality, according to Sipos et al. (2008), when its hardness is as low as possible. Response surface analysis (Fig. 2) depicts the effect of factors and their interactions on bread hardness. Bread hardness appears to increase with the rate of incorporation of gum extract and decrease with the rate of incorporation of bicarbonate and water. After analysing the data for bread hardness (Y2) as a function of gum extract (A), bicarbonate (B), and water (C), the following regression equation (Y2) was developed. This demonstrates that gum extract has a positive individual effect and water has a negative individual effect. Water also had an exponential effect on the response.

$$\mathbf{Y2} = +47 + 7.56A - 27.75C + 10.31C^2$$

3.4.2. *Consistency*

The degree of firmness or thickness of the bread is described by the consistency, which corresponds to the force required to remove (unstick) products adhering to the inside of the oral cavity during normal tasting (Sciarini et al., 2010). Response surface analysis (Fig. 3) depicts the effect of factors and their interactions on bread consistency. Bread consistency appears to increase with the rate of gum extract incorporation. Bicarbonate incorporation at a high concentration (1) increases bread consistency, but at a quantity less than 1, bicarbonate has no effect on bread consistency. Following data analysis of bread consistency (Y3) as a function of gum extract (A), bicarbonate (B), and water (C), the following regression equation (Y3) was provided. The regression equation (Y3) shows that there is an individual effect of water on the response.

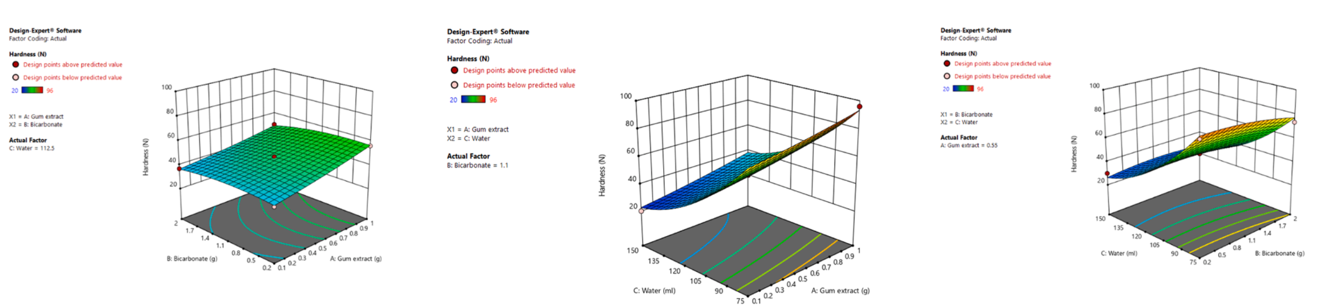
$$\mathbf{Y3} = +34.74 - 17.48C$$

3.4.3. *Masticability*

Masticability is the number of chews required to produce a solid product that is ready to be swallowed; bread is of higher quality when its masticability is as low as possible; it correlates well with sensory analysis (Chen & Opara, 2013). Response surface analysis (Fig. 4) depicts the effect of factors and their interactions on bread masticability. Bread masticability appears to increase with the rate of incorporation of gum extract and decrease with the rate of incorporation of bicarbonate. After analysing data on specific bread volume (Y4) as a function of gum extract (A), bicarbonate (B), and water (C), the following regression equation (Y4) was developed. This demonstrates that gum extract has a positive individual effect on the response and water has a negative individual effect.

$$Y4 = +192.28 + 25.66A - 77.67C$$

In fact, incorporating gum extract into bread has a negative effect on bread hardness because it increases hardness, whereas sodium bicarbonate and water have a positive effect on bread hardness because they reduce hardness. This increase in hardness with gum extract incorporation can be explained by their interaction with starch molecules, which leads to an increase in gelatinization (Gómez et al., 2007). Gum extracts interact with starch molecules during cooking, increasing their gelatinization. Thus, during the gelatinization process, when starch granules transition from an ordered to a disordered state, the textural properties of breads deteriorate, resulting in an increase in hardness (Kopjar et al., 2009). The presence of gas bubbles in the crumb influences the hardness and consistency of sour starch bread. When there



a) response surface area of bicarbonate-gum extract interactions on hardness

b) response surface area of interactions between water content and gum extract on hardness

c) response surface area of the interaction between water content and bicarbonate on hardness

Fig. 2. Effect of the interaction of various factors on hardness.

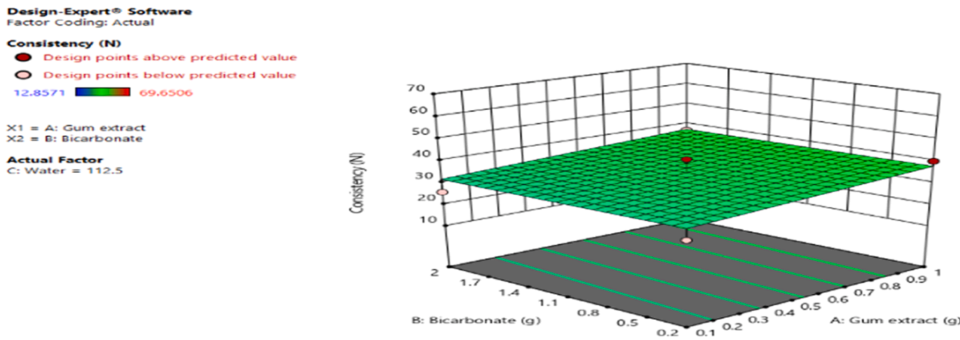


Fig. 3. Effect of interactions between different variables on consistency: Response surface space for interactions between bicarbonate and gum extract.

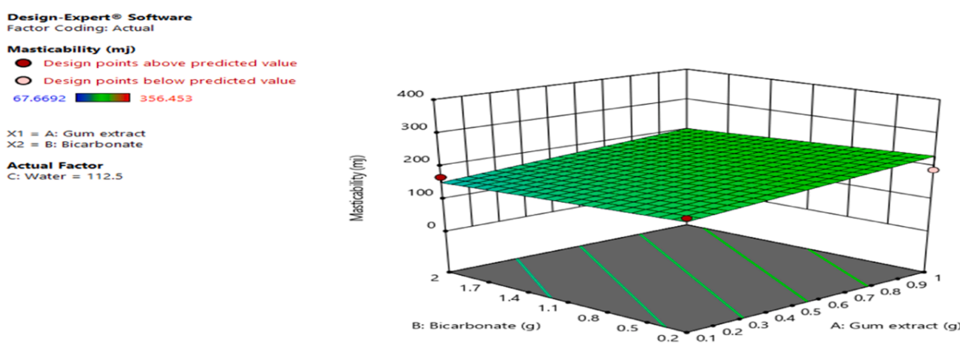


Fig. 4. Effect of interactions between different variables on chewability: Response surface space for interactions between bicarbonate and gum extract on masticability.

are fewer and smaller bubbles, the hardness and consistency increase (López & Goldner, 2015). As observed in this study, an increase in hardness results in an increase in product masticability. Similarly, as the number and size of bubbles increase, the hardness and consistency decrease. This is because bicarbonate reacts with the lactic acid in sour cassava starch, releasing carbon dioxide into the dough via an acid-base reaction. This causes the bubbles to expand, reducing the hardness,so do the masticability of the bread (Atlidakis et al., 2019). The acidic properties of cassava starch are caused by lactic acid bacteria present during starch fermentation. They produce exopolysaccharides, which are responsible for the formation of the viscoelastic structure that allows sour starch to retain gas and expand. Gums can become entangled with these exopolysaccharides, which improves gas retention and, as a result, the formation of small bubbles, resulting in a harder crumb. In terms of masticability, the degree of dehydration of the crumb has a significant influence. Crumbs have lower masticability values at higher levels of dehydration (López & Goldner, 2015). Singh et al. (2016) found similar results in their study on the development of gluten-free rice muffins using black carrot dietary fibre concentrate and xanthan gum, where they observed an increase in hardness with the addition of xanthan gum. Furthermore, the interaction of sodium bicarbonate with starch molecules reduced gelatinization and thus hardness. (Fernández et al., 2020) discovered a reduction in hardness with the addition of chemical surfactants in their study of the effect of chemical surfactants on the rheological and textural properties of bakery products.

3.5. *Effect of factors and response surface analysis on cohesion*

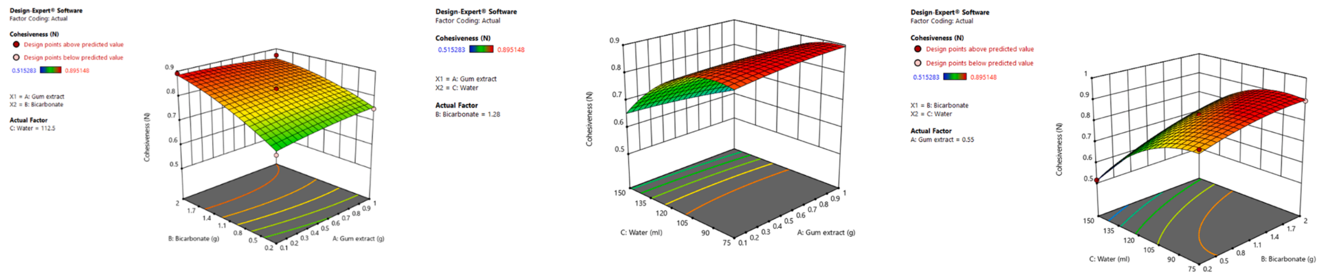
Cohesion is defined as resilience, which is defined as the ratio of energy recoverable when the first compression is released, or the amount of internal strength in a material's structure that determines a substance's ability to stick to itself (Kaur et al., 2015). When a product has high cohesion, it is more resistant to handling during manufacturing, packaging, and marketing. As a result, it is more likely to be presented to customers in the desired state (Singh et al., 2016). Response surface analysis (Fig. 5) depicts the effect of factors and their interactions on bread cohesion. Bread cohesion appears to decrease with the rate of incorporation of gum extract and increase with the rate of incorporation of bicarbonate. Water incorporation increases cohesion in small amounts but decreases it in amounts greater than 90 ml. The following regression equation (Y5) was developed after analysing the data for bread cohesion (Y5) as a function of gum extract (A), bicarbonate (B), and water (C). Bicarbonate has a positive individual effect, water has a negative individual effect, and bicarbonate and water have a positive quadratic effect. Water had a negative exponential effect on the response as well.

$$\mathbf{Y5} = +0.8306 + 0.00664\text{B} - 0.1271\text{C} + 0.0269\text{BC} - 0.0793\text{C2}$$

In fact, the decrease in cohesion caused by gum extract means that gum extract has a negative effect on the response, whereas sodium bicarbonate and water have a positive effect by increasing cohesion. Cohesion also provides information on sensory brittleness, density perception, and the amount of energy required to chew the food (Sánchez et al., 2009). These findings contradict those of Martínez et al. (2015), who observed an increase in cohesion with the addition of carboxymethylcellulose (CMC) to the physicochemical properties and baking quality of gluten-free bread made from rice flour, corn starch, and cassava starch. This variation can be explained by the fact that the interactions between the molecules differ depending on the type of hydrocolloid used.

3.6. *Effect of factors and surface analysis of responses on elasticity*

Elasticity is an important characteristic of bread quality, indicating the ability of the sample to regain its height between the end of the first compression and the beginning of the second (Shevkani & Singh, 2014). The Response surface analysis (Fig. 6) depicts the effect of factors and their interactions on bread elasticity. It appears that the incorporation



a) Response surface area of bicarbonate-gum extract interactions on cohesion

b) Response surface area of interactions between water content and gum extract on cohesion

c) response surface area of the interactions between water content and bicarbonate on cohesion

Fig. 5. Effect of different factors on cohesion.

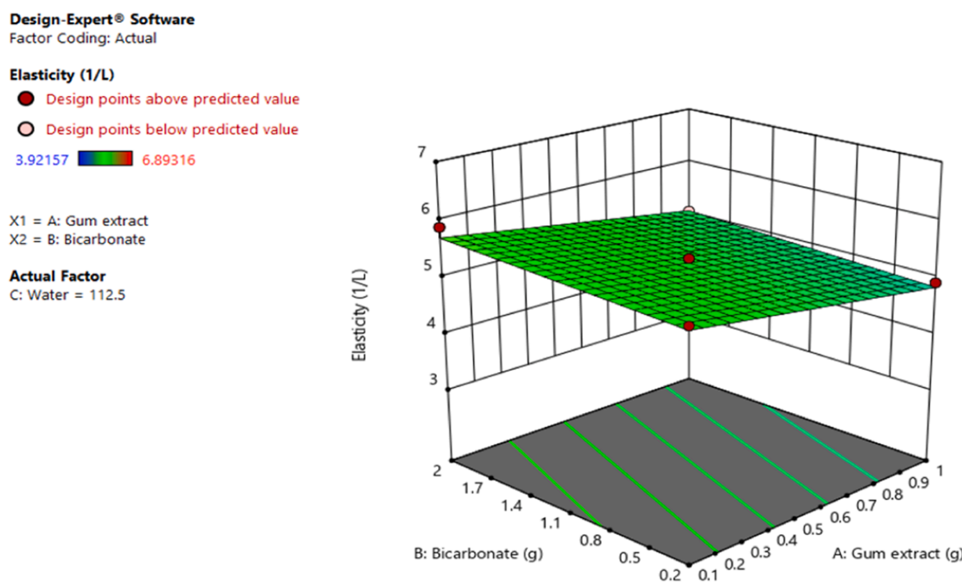


Fig. 6. Effect of variable interactions on elasticity: Response surface space for bicarbonate and gum extract interactions on elasticity.

rate of gum extract reduces bread elasticity while increasing the incorporation rate of bicarbonate. After analysing the bread elasticity data (Y6) as a function of gum extract (A), bicarbonate (B), and water (C), the following regression equation (Y6) was developed. This demonstrates that gum extract has a negative individual effect on the response and water has a positive individual effect.

$$Y6 = +5.27 - 0.3217A + 1.10C$$

Indeed, the higher the elasticity values, the better the bread quality, because elasticity is associated with a fresh, aerated product (Campbell & Martin, 2020). Thus, the decrease in elasticity caused by gum extract means that gum extract has a negative effect on response, whereas sodium bicarbonate and water have a positive effect by increasing elasticity. The degree of bonding between structural elements is reflected in the increase in elasticity. As a result, greater elasticity implies less deformation or breakage of the composites network. Consumers expect products to be less elastic and smoother, so this textural property is important. These findings support those of Papalia et al. (2015), who developed low-calorie cheese breads by partially substituting fats with guar and xanthan gums.

3.7. Optimum conditions for bread production

A compromise between the various optimal conditions obtained for each response was reached, and an optimal formulation was chosen (Fig. 7): The resulted terms are the following: Extract gum (0.28 g), bicarbonate (1.99 g) and water (112.5 ml) resulted. Table 3 shows the responses, and it appears to be no significant difference between experimental and predicted values. This confirms the model's validity once more.

3.8. Pasting properties (RVA)

An analysis of the RVA parameters on the SPC flour and the optimal flour was performed to understand the effect of gum extract incorporation on the gelatinization and retrogradation process of optimal flour. The viscoamylograms of SPC flour and optimum flour are shown in Fig. 8. It appears that viscosity increases from a specific temperature (Pasting temperature) until peak viscosity is reached at a specific temperature (Peak Temperature). Following this temperature, viscosity decreases with decreasing temperature until a plateau is reached (Holding Viscosity). Breakdown is represented by the difference between peak viscosity and holding viscosity. We observed an increase in viscosity (final viscosity) after this stabilisation, and the difference between final viscosity and viscosity at the end of shearing represents retrogradation (setback). The RVA parameters for SPC flour and optimal flour are shown in Table 4. show that; the peak viscosity and the minimum viscosity breakdown, final viscosity, and setback differ significantly (p〉0.05) for both flours. However for PT °C and PT, there is no significant difference ($p<0.05$).It appears that pasting parameters increased with the addition of gum extract, and optimal flour has the highest values for all parameters.

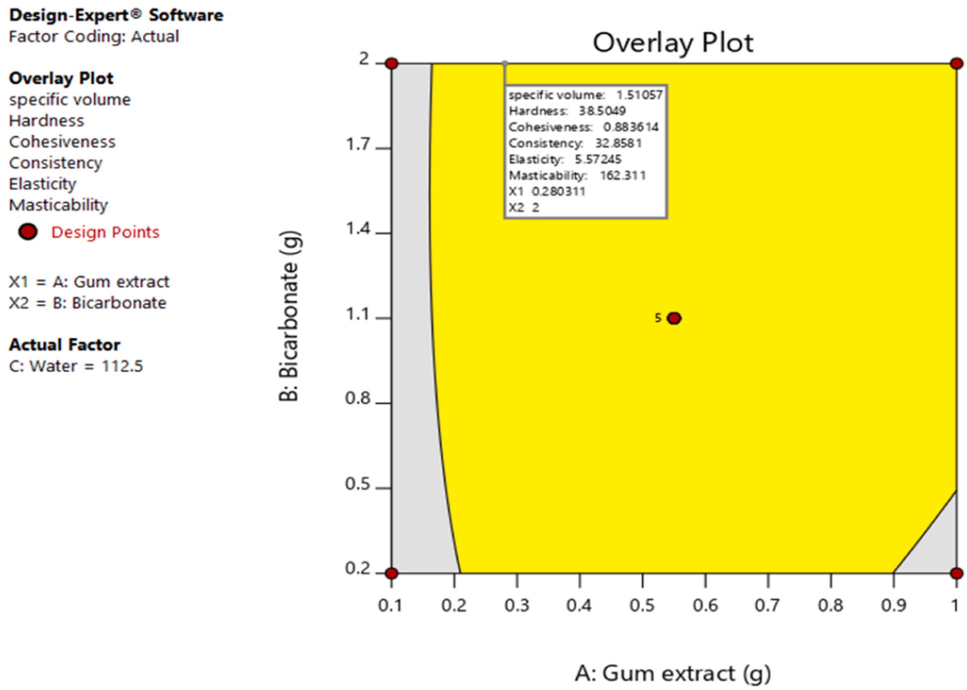


Fig. 7. Global plot of the optimal loaf.

Table 3
For the optimal condition, predicted and experimental responses were obtained under the same conditions.

Responses	Predicted optimal values	Experimental optimal values	Desirabily
Spc volume (Cm^3 /g)	1.51	$1.53^a \pm 0.02^a$	0.746
Hardness (N)	38.51	$38.49^a \pm 3.03^a$	
Cohesion	0.88	$0.9^a \pm 0.2^a$	
Consistency (N)	32.86	$32.82^a \pm 2.04^a$	
Elasticity (1/L)	5.57	$5.55^a \pm 0.33^a$	
Masticability (mj)	162.35	$162.39^a \pm 5.03^a$	

Means on the same line bearing the same letters are not significantly different at the $P < 0.05$ probability threshold. N: Newton; mj: mjoule.

The increase in viscosity with the addition of gum extracts, specifically in the peak viscosity and final viscosity, is consistent with previous work on hydrocolloids. Through strong amylose-gum associations, gum has been shown to increase starch viscosity and influence starch gelatinization and retrogradation characteristics (Kowalski et al., 2008). This increase in dough viscosity caused by gum extract addition could be due to structural reorientation and an increase in interactions between certain leached molecules, primarily amylose and gums (Chandanasree et al., 2016). Indeed, when gums are impregnated into starch in aqueous solution during the kneading stage of bread-making, they are reactivated, resulting in an immediate increase in peak viscosity and final viscosity (Zarguili et al., 2006). These findings support those of Chandanasree et al. (2016), who investigated the effect of hydrocolloids and heat on the physicochemical properties of cassava starch on thermal properties. With carboxy-methylcellulose and dry heating, bonding and morphological properties, as well as peak viscosity and final viscosity, increased significantly.

3.9. Sensory profile of the SPC bread and optimal bread

Fig. 9 depicts the sensory profiles of the SPC and optimal breads. The optimal bread scores are greater than 5 on a 9-point scale for all sensory attributes, indicating that it is satisfactory, with the optimal bread

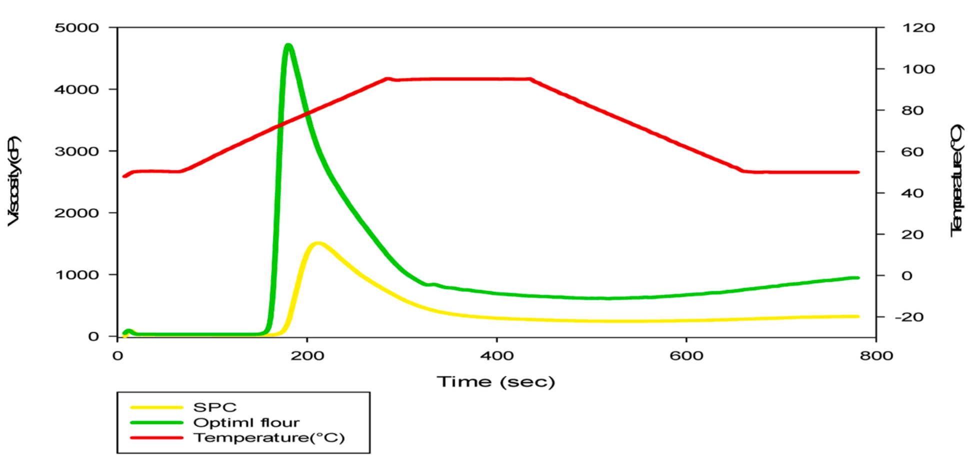


Fig. 8. Viscoamylogram SPC flour and optimum flour.

Table 4
Pasting properties of SPC Flour and Optimum.

Parameters	Optimale flour	SPC flour
PV (Cp)	2361.25±11.67 [a]	1509±7.46[b]
MV(Cp)	325.75±5.65 [a]	273±4.74[b]
BD(Cp)	2035.5 ± 15.53 [a]	1236±9.43[b]
FV(Cp)	473.25±4.33 [a]	321±2.94[b]
SB(Cp)	1888±19.75 [a]	1188±12.43[b]
PT(S)	780±0.00[a] [a]	780±0.00[a]
PT °C(Cp)	50.4 ± 0.00 [a]	50.4 ± 0.00[a]

At $P<0.05$, values with different letters differ significantly. The viscosity of straw, MV stands for minimum viscosity, BD: Breakdown, FV stands for final viscosity, SB stands for setback. PT: Peak time, PT °C: Pasting temperature, Cp stands for centipoise, Second (S).

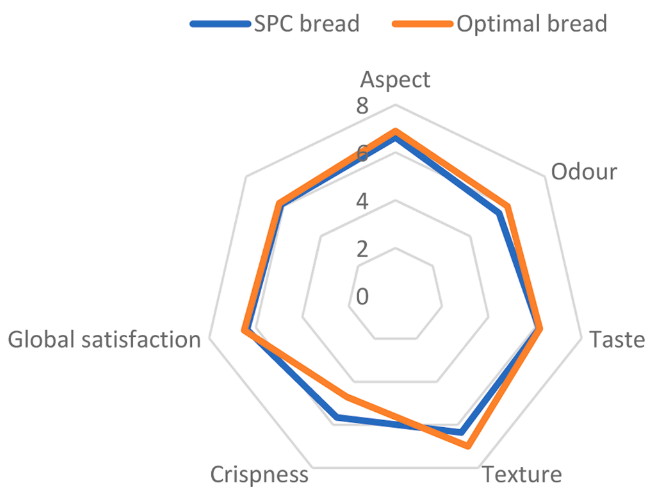


Fig. 9. Sensory profile of the SPC bread and optimal bread.

having a higher acceptability value (6.21±1.33[a]) than the SPC bread (6.12±1.07[b]). There is a significant difference between (P⟩0.05) the two bread for all descriptors, with the exception of the taste, which has values of 6.2 ± 1.53 [a] for optimal bread and 6.18±1.32 [a] for SPC bread. Indeed, incorporating gum extracts and bicarbonate in the formulation has no effect on the taste because they are functional agents that improve food texture, moisture retention, and delay starch retrogradation (Kohajdová & Karovičová, 2009). This can also explain the fact that the optimal bread is superior to SPC bread in appearance (6.9 ± 1.28 [a]), odour (6.00±1.65 [a]), texture (7.00±1.30 [a]), and overall satisfaction (6.5 ± 1.51 [a]). These findings support those of Zapata et al. (2019), who found that guar gum modified the physical properties of sour starch and cheese bread; similarly, Xiao et al. (2023) discovered that incorporating bicarbonate improved the functional and sensory properties of fermented rice flour-based spaghetti. However, optimal bread has lower crispness than SPC bread. This can be explained by the fact that the addition of gum extracts increased the rate of water incorporation, resulting in a softening of the bread crust and crumb. Furthermore, the bicarbonate's action would have caused carbon dioxide to form in the crust, lightening the bread and reducing its crispness. The reduction in crispness caused by the addition of gum extract, bicarbonate, and water can be attributed to the increased incorporation rate of water in the formulation. These findings are consistent with those of (Guarda et al., 2004), with the incorporation of alginate gums and HPMC.

3.10. Bread colour

The influence of gum extracts in the formulation of bread based on sour cassava starch, cowpea flour, and peanut powder on bread colour was evaluated by measuring the colour parameters (L. a. b and WI), which are shown in Table 5. The values of (L) represent the brightness or luminance of the flour, and the higher the value of L, the lighter the flour is. The values of (a) represent green-red balance and (b) blue-yellow balance. The whiteness index (WI) measures the overall whiteness of food products and can indicate the degree of discoloration that occurred during the drying process. We discovered a significant difference (p⟩0.05) between SPC and optimal bread after analysing the various colour parameters. Indeed, the L, a, and WI parameters of our Optimal bread are lower than those of the SPC bread, while a the a parameter of the optimal bread is higher than that of the SPC bread. As a result, the incorporation of gum extract reduces the brightness and whiteness of the bread.

The low value of the parameters L and WI of the bread containing the gum extract indicates that the brightness and whiteness of the bread decrease with the addition of the gum extract. This is explained by the fact that the *Truimfetta pentendra* gum extract obtained was very dark, due to its intrinsic coloration, but much darker due to non-enzymatic browning that occurred during the various stages of extract preparation, most notably drying of the bark, aqueous extraction at 50 °C, and extract drying at 50 °C. Therefore, the brightness and whiteness of the bread decreases with the incorporation of the gum extract. Most previous research on the effect of hydrocolloids on the colouring of gluten-free breads (Mezaize et al., 2009; Zapata et al., 2019) has found that hydrocolloids affect the distribution of water in the dough, which has a direct influence on the Maillard reaction and caramelization. Furthermore, not only does the work referred to her use pure gums, but the manufacturing process prevents gums from non-enzymatic browning.

4. Conclusions

This study found that gum extract has a positive influence on the specific volume of breads at moderate incorporation rates, but a negative influence on textural properties. Bicarbonate and water (up to a certain incorporation threshold) have a positive influence on the specific volume and textural properties of breads. The optimum proportions of gum extract, bicarbonate, and water are 0.28 g, 1.99 g, and 112.5 ml, respectively. This yields a specific volume of 1.51 Cm^3/g, a hardness of 38.51 N, a cohesion of 0.88, a consistency of 32.86 N,anelasticity of 5.57 (1/L), and a masticability of 162.35(mj). The incorporation of gum extract and bicarbonate increased the pasting properties of the flours, confirming the assertion that the combination of hydrocolloids (gum extract) and bases (bicarbonate) with a composite flour based on sour cassava starch, peanut and cowpea flour modifies it bread-making ability. Thus, this analysis suggest that *truimfetta pentendra* gum extract is appropriate for the development of gluten-free products and can be used to solve problems associated with the use of wheat flour in bread-making.

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Table 5
SPC bread and optimal bread color.

Parameters	SPC bread	Optimal bread
L	66.88±0.01[a]	61.52±0.01 [b]
a	4.07±0.03 [b]	4.18±0.02 [a]
b	12.83±0.01 [a]	10.8 ± 0.01 [b]
WI	99.91±0.0005 [a]	99.67±0.0003 [b]

*

At the 0.05 level, there is no significant difference between results with the same letters in the same row. L: the brightness of the flour. a: balance of green and red. b: balance of blue and yellow. WI stands for the whiteness index.

Ethical statement

Informed consent was obtained from all subjects involved in the study

CRediT authorship contribution statement

Marie Madeleine Nanga Ndjang: Writing – original draft, Supervision, Software, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Julie Mathilde Klang:** Writing – review & editing, Visualization, Validation, Supervision, Project administration, Methodology, Conceptualization. **Bilkissou Njapndounke:** Writing – review & editing, Methodology. **Marius Edith Kouam Foko:** Writing – review & editing, Methodology. **Jean Roger Dongmo:** Writing – review & editing, Methodology. **Michael Hermann Kengne Kamdem:** Writing – review & editing, Methodology. **Jordan Lembe Tonga:** Writing – review & editing, Methodology. **Edwin Mpho Mmutlane:** Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization. **Derek Tantoh Ndinteh:** Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization. **Eugenie Kayitesi:** Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization. **François Ngoufack Zambou:** Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization.

Declaration of competing interest

The authors declared that they have no conflict of interest.

Data availability

Data will be made available on request.

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