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RHEOLOGICAL PROPERTIES OF BREAD DOUGH ENRICHED WITH GROUND, TOASTED AND SPROUTED CHIA SEEDS

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Abstract– The study aimed to explore the rheological characteristics of bread dough prepared by varying the ratios of pretreated chia seeds (CS) to refined wheat flour. Various rheological properties, including water absorption, dough development, extensibility, proofing time, tolerance index, and gelatinization, were assessed using the Brabender Farinograph E, Extensograph E, and Amylograph E instruments. Throughout the investigation, the proportion of refined wheat flour was kept constant, while the chia seed (CS) ratio was altered with different pre-treatments at 2%, 4%, and 6% levels, including germination (G), grinding/untreated (U), and roasting (R). Water absorption values (500 B.U.) ranged from 64.1% to 68.7%, while water absorption values (14.0%) varied from 63.2% to 67.8%. For samples labeled T0 to T9R6, the dough development times (DDT) across the various flour blend formulations spanned from 5.7 to 7.2 minutes. The tolerance index improved progressively from sample T0 to T3G6 with the inclusion of CS flour, increasing from 74 to 81 BU (Brabender Unit). Extensograph values were measured at curves corresponding to proofing periods of 30, 60, and 90 minutes. As proofing time increased, the energy area decreased and extension resistance rose. All sample ratio values fell within the range of 1.7 to 5. When roasted chia seeds were mixed with untreated (powdered) chia seeds and refined wheat flour, the amylographic parameters of the amylogram peak maximum, temperature, and gel viscosity were enhanced. T8R4 achieved the highest peak at 60.8 °C, followed by T7R2 and T4U2 at 60.4°C and 59.3°C, respectively. These findings underscore that incorporating CS flour improves the rheological properties and overall quality of the flour dough. Such dough can be employed in the production of bread and other bakery products due to its high nutritional value and beneficial impact on human health.

INTRODUCTION

Chia (*Salvia hispanica* L.) originated from areas in Central America (Guatemala and Mexico), but is presently also cultivated in Argentina, Australia, Colombia, Bolivia, Peru, Europe, and America Grancieri *et al*., (2019). The high nutritional value of chia seeds is a result of the contents of fat (30–34%), protein (15–26%), carbohydrates (26–41%) and dietary fiber (18–30%) (Ixtaina *et al.,* 2008). The content of individual components depends on the variety as well as the environmental and growing conditions (Ayerza, 2005). The chia seed is a good source of protein 19-27 % (Weber *et al.,* 1991) which is higher than some of other traditional crops such as wheat, corn, rice, oat, barley and amaranth (Ayerza and Coates, 2005).

Responding to the evolving preferences of consumers, the food industry is continuously innovating and tailoring products that not only meet quality expectations but also offer health benefits. This shift is largely driven by the pressing need to combat the growing global incidences of non-communicable diseases, as pointed out by Oomah and Mazza, 1998. In recent times, the bakery sector stands out as one of the steadily growing segments in the food processing industry. There's a notable surge in the demand for wheat-based items in India. In fact, by 2022, the valuation of the Indian bakery market reached a whopping US$ 11.3 Billion. With the current trajectory, market experts anticipate this number to climb to US$ 21.2 Billion by 2028, reflecting a CAGR of 11.06% during the 2022-2028 periods. Reflecting the public's growing emphasis on health and nutrition, breads enhanced with functional ingredients are gaining popularity.

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Varieties enriched with garlic, mixed grains, and other cereals are now commonly found on store shelves. Hence this study was undertaken with the objective of determining the rheological properties of dough mixed with roasted, germinated and grounded chia seed.

MATERIALS AND METHODS

Materials

Refined wheat flour, chia seed were procured from local market in Prayagraj. Chia seeds were pretreated and grounded, i.e. allowed for germination (42 to 48 hours), untreated, i.e. only grounded and roasted. After wheat flour was taken, flours were fortified according to 2%, 4% and 6% ratio with chia seed and the portion of refined wheat flour was kept constant.

Methods

Various rheological properties, including water absorption, dough development, extensibility, proofing time, tolerance index, and gelatinization, were assessed using the Brabender Farinograph E, Extensograph E, and Amylograph E instruments. Throughout the investigation,

Farinograph Test

The Farinograph test gauges the rheological properties of flour by measuring the dough's resistance to mixing. A 300g flour sample, with a moisture content of 13.2%, was placed in the designated Farinograph mixing bowl. To this, water was gently added from a burette. The flour mixture was also supplemented with 2 g/100 g of salt. The analysis was performed using a 300g Brabender Farinograph (Brabender GmbH & Co. KG, Germany), adhering to the standard procedures outlined by AACC (2000). Key attributes recorded during the test include the water volume needed to attain a 500 BU consistency (water absorption), the time taken to reach this consistency (development time), the duration the dough maintains this consistency (dough stability time), and the extent of softening observed after 7 minutes.

Extensiograph Test

The Extensiograph is an instrument designed to gauge the dough's elasticity and resistance to stretching. It calculates the force needed to stretch the dough using a hook until the point of rupture. In this research, the characteristics of bread dough enriched with chia seed flour in its germinated, roasted, and grounded forms was assesed utilizing the Extensograph-E from Brabender GmbH & Co. KG. The test yielded data on the energy value (represented by the area under the curve in cm^2), resistance to stretching (R, in BU), dough stretchability (E, in mm), and the R/E ratio. Measurements were taken at intervals of 30, 60, and 90 minutes, following the established guidelines from AACC (2000).

Amylograph Test

The Amylograph test assesses dough quality, specifically bread dough, by gauging its viscosity during heating and cooling. This provides insights into dough's gelatinization and starch qualities. Using specialized Amylograph equipment (Brabender GmbH & Co. KG, Germany), an 80g flour sample was combined with 450 ml of water. The equipment measures viscosity changes over time. Gelatinization in this context means the starch granules' water absorption and swelling, leading to dough thickening. The onset of gelatinization, indicated by a significant viscosity increase due to starch granule swelling, is vital as it denotes flour quality. Lower gelatinization temperatures signify better flour gelatinization properties, while flours with higher temperatures might have constrained water absorption and starch paste stability.

RESULTS AND DISCUSSION

Effect of Pretreated Chia Seed (CS) on Farinograph Parameters

Understanding the rheological attributes of dough aids in anticipating its processing behaviors and ensuring consistent food quality. As outlined in Table 1, at a moisture content of 13.2%, the water absorption for a consistency of 500 B.U. was 64.1%. For the T0 sample, it was 63.2% at 14% moisture. Depending on the quantity of CS flour integrated, the water absorption potential varied from T1G2 to T9R6. The overall range was 66.4%-68.7% for 500 B.U. and 65.5%-67.8% for 14%. Water absorption, symbolized by the curve's peak, gauges the water amount needed for standard dough consistency. Trejo-Gonzallez *et al.* (2014) observed that substituting wheat flour with 10-20% sweet potato flour yielded somewhat comparable results. Due to the hydrocolloid behavior of mucilage in CS, which soaks up multiple times its weight, increased water absorption was evident.

The development time is the period of time that elapses between the addition of the initial water and the point at which the dough reaches its maximum torque. The water hydrates the constituent elements of the flour at this step of mixing, causing the dough to form. Dough development time (DDT) of chia seed-infused dough shown in range of 5.7 to 7.2 in which germinated cs infused dough shown low DDT, i.e. 6.2 to 5.8 and highest DDT was shown in Untreated cs infused dough, i.e. 7.2 to 6.7 the simultaneous diluting effect of non-gluten proteins causes an increase in either water absorption or dough development time (DDT) and a decrease in dough stability time at all flour replacement levels by PLP, similar to the effect of Chia whole flour substituted with wheat flour in dough and bread at 5% (Iglesias-Puig and Haros, 2013).

Dough Stability Time (DST) decreased in germinated CS samples but rose for roasted and untreated CS samples. Table 1 indicates the greatest DST in roasted CS-infused dough at T7R2 (7.9 min) and the least for T2G4 (6.3 min). The dough's strength is indicated by its stability. Brown bread dough exhibited higher stability time compared with the white bread dough, which could be attributed to the higher fiber content in the brown bread flour Gómez *et al.* (2003) Gómez *et al.* (2008).

The Mixing Tolerance Index (MTI) is the variance in Brabender units noted 5 minutes post the curve's peak. Table 1 highlights that MTI ranged between 60 to 81 BU, increasing with CS addition. Vernaza (2011) deduced that green banana flour inclusion amplified MTI due to diminished mechanical action tolerance during extended mixing.

Breakdown time, which gauges the time taken for torque to drop from its peak, was longest for samples T7R2 and T4U2 at 10 minutes and shortest for T3G6 at 8.0 minutes.

Impact of Pretreated Chia Seed (CS) on Extensiograph Parameters

Extensograph tests shed light on the dough's viscoelastic properties, evaluating its flexibility and resistance to stretching. A harmonious balance of resistance and stretchability yields dough with ideal characteristics. Employing an extensograph from Brabender, Duisburg, Germany, various parameters like dough's resistance to extension (BU), its extensibility (mm), and the peak energy for dough extension were discerned. Multiple parameters can further define the ratio number, as presented in Table 2.

Table 1 elucidates the extensographic readings of the samples at resting intervals of 30, 60, and 90 minutes. For the T0 sample, the energy value (cm^2) oscillated between 35 and 79 cm^2, representing the area under the curve. Notably, all samples' energy areas dwindled with increased proving durations. This dough energy, indicative of the effort to stretch the dough until tearing, serves as an apt metric of a flour's baking potential (often termed as 'flour strength' in baking jargon. A spike in energy can be attributed to enhanced dough extensibility.

Sample T8R4 exhibited maximum resistance to extension at 540 BU post a 30-minute rest. Subsequent readings for sample T9R6 stood at 476 BU (30 minutes), 389 BU (60 minutes), and 231 BU (90 minutes). As the proving duration expanded, a marked increase in resistance was noted. The R/E ratio (flour's resistance to its extensibility) serves as

Table 1. Effect of pretreated Chia seed (CS) on farinograph parameters

Sample	Moisture content	WA500 (BU)	WA (14%)	Devolopment Time (min)	Stability (min)	Tolarance Index (BU)	Time to breakdown (min)
T_0	13.2	64.1±0.10^a	63.2±0.20^a	5.7±0.14^a	6.8±0.17^a	74±0.18^a	7.8±0.15^a
T_{1G2}	13.2	66.4±0.32^b	65.5±0.23^b	6.2±0.17^a	6.8±0.84^a	73±0.61^a	8.2±0.32^b
T_{2G4}	13.2	68.2±0.15^c	67.3±0.19^c	5.8±0.32^a	6.5±0.14^b	80±0.17^b	8.1±0.17^b
T_{3G6}	13.2	68.7±0.18^c	67.8±0.11^c	6.0±024.^{a}	6.3±0.21^b	81±0.21^b	8.0±0.51^b
T_{4U2}	13.2	68.2±0.34^c	67.3±0.18^c	7.2±0.40^b	7.8±0.44^c	51±0.32^c	10±0.19^c
T_{5U4}	13.2	68.3±0.20^c	67.4±0.23^c	7.0±0.32^b	7.5±0.24^c	55±0.47^c	9.6±0.62^c
T_{6U6}	13.2	68.1±0.24^c	67.2±0.28^c	6.7±0.64^c	6.5±0.19^b	57±0.14^c	9.0±0.20^c
T_{7R2}	13.2	68.3±0.10^c	67.4±0.08^c	7.0±0.48^b	7.9±0.26^c	47±0.30^c	10.0±0.17^c
T_{8R4}	13.2	68.1±0.15^c	67.2±0.22^c	6.0±0.41^a	7.0±0.30^c	48±0.74^c	9.0±0.30^c
T_{9R6}	13.2	68.4±0.32^c	67.5±0.17^c	6.0±0.32^a	5.6±0.87^b	60±0.37^c	8.3±0.22^b

(*$_G$ = Germinated, $_U$ = Untreated/powdered, $_R$ = Roasted, BU = Brabender unit. Different letter in each column a,b,c indicates a significant difference $p < 0.05$).

a comprehensive metric; a high value signals increased resistance and diminished extensibility. Doughs with higher rigidity exhibit reduced expansion capabilities, but an uptick in dough tension boosts its water and gas retention, refining bread texture. However, this observation diverges from the insights of Naghavi *et al.* (2011) on wheat flour's substitution. In Table 2 the ratio figures for samples span between 1.7 and 5.0. Notably, this ratio underwent fluctuations in samples T0 to T9R6 based on varying proving durations.

Effect of pretreated chia seed (CS) on Amylograph parameters

The values of the gel's essential rheological characteristics are shown in Table 3. It measures the viscosity of a dough sample as it is heated and chilled, providing information about the dough's gelatinization and starch quality. A conventional amylographic curve with the peak viscosity under slurry heating was plotted in the studies described. Peak crumb viscosity dropped consistently during post-baking storage of bread and was further reduced by malt additions to the bread formula. When viscosity decreased (Yasunaga *et al*., 1968) or increased (Xu, 1985), some writers found seemingly contradictory results. Table 3 Brabender Amylograph

The amylograph serves as a precise instrument for assessing starch gelatinization and enzyme activity in bread flour. In the case of the T0 (control) sample, gelatinization commences at 59.5 °C. The amylographic parameters, including peak maximum, temperature and exhibited an upswing when dough comprised blends of roasted CS and untreated (powdered) CS with refined wheat flour.

Table 2. Effect of pretreated chia seed (CS) on extensiograph parameters

Sample	Proving Time (min)	Energy (cm^2)	Resistance to extension (BU)	Extensibility (mm)	Extensibility Maximum (BU)	Ratio number
T_0	30	67±0.30^a	316±0.36^a	144±0.15^a	344±0.20^a	2.2±0.12^a
	60	64±0.45^b	312±0.41^a	138±0.65^a	330±0.32^a	2.3±0.11^a
	90	57±0.62^b	298±0.68^a	130±0.10^a	306±0.84^a	2.3±0.10^a
T_1G_2	30	60±0.12^b	372±0.47^a	119±0.11^b	373±0.68^a	3.1±0.20^b
	60	56±0.14^a	298±0.61^a	133±0.23^a	300±0.65^a	2.2±0.32^a
	90	57±0.21^b	283±0.15^a	143±0.55^a	286±0.41^b	2.0±0.41^a
T_2G_4	30	53±0.51^b	312±0.69^a	119±0.51^b	320±0.22^a	2.6±0.42^a
	60	47±0.45^c	239±0.20^b	132±0.29^a	246±0.54^b	1.8±0.20^c
	90	47±0.21^c	244±0.45^b	132±0.32^a	248±0.43^b	1.8±0.21^c
T_3G_6	30	35±0.20^c	206±0.17^b	119±0.10^b	257±0.13^b	1.7±0.03^c
	60	37±0.34^c	221±0.37^b	113±0.48^c	275±0.30^b	2.0±0.51^a
	90	38±0.26^c	227±0.12^b	116±0.25^b	287±0.41^b	2.0±0.31^a
T_4U_2	30	63±0.42^b	364±0.18^a	129±0.30^b	365±0.47^a	2.8±0.10^b
	60	54±0.19^b	312±0.39^a	131±0.11^a	313±0.21^a	2.4±0.74^a
	90	43±0.15^c	254±0.61^b	120±0.20^b	256±0.24^b	2.1±0.19^a
T_5U_4	30	60±0.27^b	350±0.46^a	134±0.36^a	350±0.30^a	2.6±0.32^a
	60	54±0.62^b	277±0.61^b	138±0.85^a	277±0.12^b	2.0±0.74^a
	90	55±0.43^b	264±0.85^b	143±0.40^a	270±0.15^b	1.8±0.11^c
T_6U_6	30	59±0.33^b	362±0.24^b	134±0.18^a	371±0.06^a	2.7±0.62^a
	60	50±0.10^c	289±0.32^a	118±0.65^b	299±0.30^b	2.5±0.34^a
	90	48±0.16^c	241±0.41^b	142±0.35^a	266±0.65^b	1.7±0.30^c
T_7R_2	30	59±0.68^b	329±0.12^a	123±0.62^b	330±0.63^a	2.7±0.32^a
	60	67±0.27^a	330±0.35^a	136±0.09^a	339±0.74^a	2.4±0.14^a
	90	57±0.23^b	320±0.05^a	128±0.14^b	324±0.26^a	2.5±0.11^a
T_8R_4	30	79±0.44^a	540±0.31^c	109±0.15^c	540±0.64^c	5.0±0.24^b
	60	76±0.19^a	456±0.14^c	123±0.54^a	456±0.17^c	3.7±0.30^b
	90	71±0.62^a	404±0.10^c	124±0.75^b	407±0.41^c	3.2±0.14^b
T_9R_6	30	73±0.74^a	476±0.16^c	114±0.64^c	489±0.20^c	4.2±0.17^b
	60	64±0.45^a	389±0.54^c	120±0.68^b	399±0.47^c	3.2±0.20^b
	90	45±0.17^a	231±0.44^b	133±0.32^a	234±0.54^b	1.7±0.32^c

(*$_G$ = Germinated, $_U$ = Untreated/powdered, $_R$ = Roasted, BU = Brabender unit. Different letter in each column a,b,c indicates a significant difference $p < 0.05$).

Table 3. Effect of pretreated chia seed (CS) on Amylograph parameters

Sample	Begin of gelatinization (ºC)	Gelatinization Temp (ºC)	Gelatinization max (AU)
T_0	59.5±0.10[a]	90.3±0.14[a]	1716±0.41[a]
T_{1G2}	57.9±0.21[b]	89.6±0.20[b]	2117±0.12[b]
T_{2G4}	56.4±0.32[b]	90.6±014[a]	1924±0.41[c]
T_{3G6}	57.1±0.51[b]	90.1±0.22[a]	1777±0.57[a]
T_{4U2}	59.3±0.14[a]	89.6±0.35[b]	2068±0.32[b]
T_{5U4}	58.6±0.62[a]	90.4±0.49[a]	2000±0.51[b]
T_{6U6}	57.1±0.33[b]	90.4±0.23[a]	2056±0.15[b]
T_{7R2}	60.4±0.24[c]	90.6±0.15[a]	1786±0.74[a]
T_{8R4}	60.8±0.32[c]	89.8±0.20[b]	1992±0.55[c]
T_{9R6}	59.1±0.47[a]	89.6±0.11[b]	1740±0.34[a]

(*$_G$ = Germinated, $_U$ = Untreated/powdered, $_R$ = Roasted, BU = Brabender unit. Different letter in each column a,b,c indicates a significant difference $p < 0.05$).

T8R4 achieved the highest peak point at 60.8°C, closely followed by T7R2, T4U2, and T5U4 at 60.4°C, 59.3°C, and 58.6°C, respectively. Conversely, the onset of gelatinization was lowest for T2G4 at 56.4°C, with T_3G_6 and T_6U_6 close behind at 57.1 °C. This drop in gelatinization onset temperature is attributed to the germination process. During germination, the activity of various enzymes involved in the digestion of starch, lipids, proteins, hemicellulose, and phosphates undergoes a rapid increase. These hydrolytic enzymes transform complex food components into simpler forms, making them more accessible for consumption and transfer by the embryo, Guzman-Ortiz *et al*. (2019).

CONCLUSION

The study delved into the ramifications of amalgamating Chia Seed (CS) with refined wheat flour on the dough's rheological attributes and overall quality. By integrating CS flour into the mix, a pronounced impact was observed on the dough's rheological characteristics. This influence was meticulously assessed using three primary tools: farinograph, extensograph, and amylograph. The farinograph analysis, which essentially measures dough's consistency over time, revealed that the stability duration of the dough ranged between 6.3 to 7.9 minutes, showcasing a variance when juxtaposed with the control sample. As the proportion of CS flour increased in the dough mix, there was a noticeable ascent in both the tolerance index and the time it took for the dough to break down. However, what stands out is that the infusion of CS flour didn't merely impact the dough's properties incrementally but accentuated its rheological features more holistically. Drawing insights from the extensograph, which measures the dough's elasticity and resistance to extension, the integration of chia seed flour seemed to enhance the dough's rheological aspects. There was a noted increase in the dough's resistance to extension and its extensibility values, especially during the critical 90-minute proving phase, as opposed to the control sample.

Collating the data from these meticulous tests, one could unequivocally deduce that incorporating chia seed flour doesn't just marginally augment the rheological features. Instead, it significantly elevates the overall quality and characteristics of the blended flour dough, making it a promising ingredient for future baking endeavors.

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