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Effect of flaxseed addition on rheological, texture and color characteristics of peanut butter

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Abstract
In this study the effect of flaxseed addition on peanut butter rheology, textural characteristics and color at different level of fortification (10-30%) was investigated. Rheological parameters such as storage modulus (G'), loss modulus (G") were measured using stress and frequency sweeps at 20 ºC and 35 ºC and it was found that all the fortified samples maintained the viscoelastic nature of peanut butter at both the temperatures. The value of G' and G" was affected by the temperature, frequency sweep tests showed that the value of both G' and G" decreased in the entire fortified sample at 35 ºC as compared to samples at 20 ºC. Results obtained by sweep tests were fitted adequately to the Herschel Buckley model and demonstrated the psuedoplastic (shear thinning) behavior in all the fortified samples. Addition of flaxseed reduced the hardness, sickness, yield stress, storage modulus, and loss modulus as compared to control sample.

Keywords: Fortification, rheology, texture, stress sweep, storage modulus (g'), loss modulus (g")

Introduction

Peanut butter is one of the most consumed nuts spread throughout world because of its peculiar roasted peanut aroma and its richness in nutrients specially protein and polyunsaturated fatty acids [1-3]. Peanut butter is a dense suspension of peanut particles dispersed in the continuous oil phase of peanut oil [4, 5]. One of the unique properties of peanut butter is its viscoelastic nature i.e. it exhibits both solid as well as fluid like behavior [3, 4]. Peanut butter is a rich source of polyunsaturated fatty acids predominately omega 6 fatty acids but poor in omega 3 fatty acids. Omega 3 fatty acids are the essential poly unsaturated fatty acids which protects us from onset of various cardiovascular diseases [6]. One of the richest sources of omega 3 fatty acid from plant source is flaxseed. Flaxseed contains 35-46% oil (50-55% Alpha linolenic acid; a precursor of omega 3 fatty acids), 28–30% protein and 35% fiber [7- 9]. In pure peanut butter, particles of peanuts are dispersed in the continuous phase of peanut oil which is an unstabilized emulsion. In order to stabilize the peanut butter various kinds stabilizing ingredients such as esters of mono di glycerides, protein powders are added to the product [10], but use of these stabilizing ingredients lead to hardness and low liquidity of the spread i.e. decrease in the spreadibiity of the spread [11]. Flaxseed paste being rich in fat, protein and fibres especially mucilage's can be used an excellent source for stabilization of the peanut butter emulsion. Flaxseed has been incorporated in various food matrixes such as bread, biscuits and in formulation of various kinds of bakery and snacks foods as a stabilizer and emulsifier [12-14]. To understand the role of addition of flaxseed in peanut butter quantitative assessments of parameters such as spre acidity and flow ability requires the knowledge of rheological properties. Rheology helps in understanding the effect of ingredients on stability, mouth feel and structural organization of food. A lot of researches have been done on understanding the rheological behavior of peanut butter, sesame paste, and pistachio paste but there is no study at present on the texture, rheological behavior of addition of flaxseed in peanut butter [11, 15, 16]. To understand the rheological behavior of flaxseed fortification in peanut butter as a novel product various experiments were carried out with the following objectives (i) to study the effect of flaxseed incorporation on the dynamic rheological behavior of peanut butter; (ii) to study the changes in textural properties and color of the flaxseed fortification on peanut butter.

Methods and Methodology

Material

Flaxseed variety NL 277 was procured from ICAR-AICRP on linseed center, Pune; India; peanuts, peanut oil and salt were obtained from the local market of Bhopal; India. Monostearin was produced from the ABL Chemical Trading Company, Indore; India. Stevia powder was procured from Jhanil health care Pvt. Ltd. (Punjab, India).

Preparation of samples

Peanuts and flaxseed were cleaned to remove any extraneous material and damaged kernels. Peanut and flaxseed were roasted in a batch of 1 Kg in a laboratory oven (Metalab, India) separately at a temperature of 155 ºC and 127 ºC for a time period of 60 and 20 min respectively [17]. After roasting the peanut and flaxseed is allowed to cool at a temperature of 25 ºC for 30 min. After cooling the skin of roasted peanuts were removed manually and then subjected to grinding in a mixer for 5 min whereas flaxseed was grinded separately in laboratory mixer for 2 min to obtain peanut and flaxseed paste. Flaxseed paste was mixed with peanut paste as per formulation given in Table in a mini food processor along with monostearin, stevia, peanut oil and salt for 2 min for uniform mixing. The control sample was made up of peanuts along with other ingredients without flaxseed. The entire experiments were conducted in triplicates.

Table 1: Different formulation of flaxseed fortification in peanut butter (per 100 g wt. basis)

Ingredients	Control	F10	F20	F30
Peanut paste	100	90	80	70
Flaxseed paste	----	10	20	30
Peanut oil	5	5	5	5
Mon stearin	0.22	-	-	-
Stevia	0.350	0.350	0.350	0.350

Dynamic Rheology

For measurement of dynamic rheological parameters the experiments were performed in a controlled stress rheometer (Anton Parr, Germany Physical MCR 51). Probe used for analysis was parallel plate geometric configuration (PP 50 mm). To see the effect of temperature on the rheological properties of flaxseed butter and all experiments were conducted at 20 and 35 ºC respectively. The gap between the plates was set 1.0 mm and samples were loaded on the plate using a spatula. All the samples were given a pre shearing for 10 s followed by 2 min rest before starting the experiment. A pre shearing and rest was given to the samples for relaxation of residual stresses arising during loading of the samples. For oscillatory measurements stress sweep and frequency sweep were conducted in triplicates and average values were used for model parameters calculation. For determination of linear viscoelastic region (LVR), amplitude stress sweep was conducted at a frequency of 1 Hz with a shear stress range from 1-100 Pa for all the samples at 20 ºC and 35 ºC [18]. After obtaining the values of stress sweep a shear stress of 10 Pa with in linear region was applied for frequency sweep. The frequency sweep was conducted at a frequency range of 1-100 Hz with a constant shear rate of 10 Pa and at temperatures of 20 ºC and 35 ºC. For evaluating the viscoelastic nature of the sample storage modulus (G′), loss moduli (G″), were determined [6].

Rheological Models

For explaining the steady state relationship between shear stress and shear rate of flaxseed choco butter Herschel Buckley model [Eq.(1)] was used [19, 20, 21].

$\tau = \tau_0 + K.\gamma n$

Where τ (Pa) is shear stress, τ_0 (Pa) is yield stress, K (Pa s) is consistency coefficient, g is shear rate (s^1) and n is the dimensionless flow behavior index

Textural Properties

Textural properties of flaxseed spread were measured using Texture analyzer TA-XT plus of Stable Micro Systems Surrey, UK equipped with Texture Expert ™ software. Back extrusion method was used to measure the textural parameters of flaxseed butter such as Firmness (the maximum force), consistency (the positive area), and adhesiveness (the negative area). For back extrusion measurement, the sample was poured into an acrylic container (50 mm internal diameter) to a depth of 20 mm. A 40-mm disk (A/BE) and a crosshead speed of 1 mm/s with a test distance of 15 mm were the other adjustments. The tests were conducted in triplicates and results were expressed in mean ± standard error [16].

Color Measurement

Color analysis of flaxseed spread was determined in terms of CIE-LAB system (L*, a*, b* values) using Lab scan XE spectro-colorimeter (Hunter Associate Laboratory Virginia, USA, Model LX16244) following the method of Hanim *et al.*, 2016 [4]. 20 g of samples were placed in a glass sample cup and color coordinates were measured in triplicates at different spots of flaxseed fortified peanut butter [15].

Statistical Analysis

Statistical analysis of data (Turkey HSD test and Duncan's multiple range tests) was carried out to find the significant difference between the different levels of flaxseed fortified samples with control sample.

Result and Discussion

Dynamic Rheology

By estimating the dynamic rheological parameters such as storage modulus (G'), loss modulus (G") the fraction of viscoelasticity and complete strength of food matrix can be predicited [22, 23]. The knowledge of storage modulus (G'), loss modulus (G") can be used to revel food structure, organization and process ability. G' can reflect the nature of the solid-like character (elasticity); G" can reflect the nature of the liquid-like character (viscosity).

Stress Sweep

Figure 1,2,3 &4 shows the stress sweep results for a representative formula prepared using flaxseed incorporation at different temperatures (20 and 35 ºC) combination. Within the linear region, both elastic and viscous moduli are stress-independent up to 15 Pa. After shear stress of 15 Pa, the decreasing deviation from linearity in all samples and at all temperatures can be corresponded by breaking bonds. It can be seen that the width of the linear viscoelastic region depends on temperature. The deviation from linearity and the disruption of structure was sharper in higher temperatures. To ensure the test was conducted in LVR, 10 Pa shear stress was selected for all samples at all temperatures. A similar result was obtained by Emadzadeh *et al.*, 2013 [16] for low calorie pistachio butter.

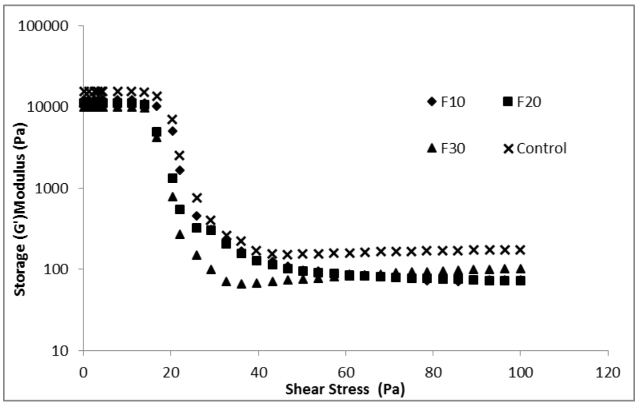

Fig 1: Stress sweep data showing variation in storage modulus for flaxseed fortified peat nut spread samples (F10, F20 and F30) and control sample at 20 ºC.

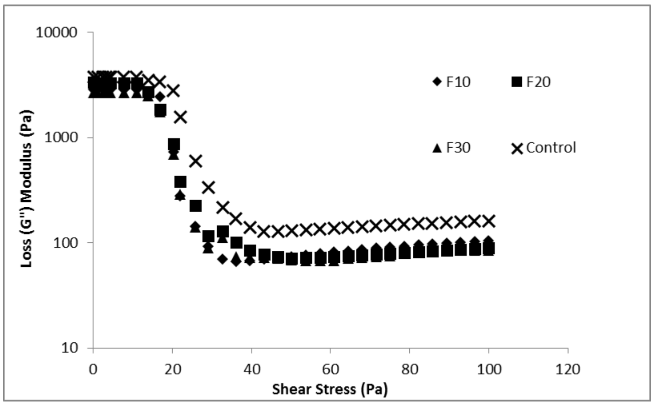

Fig 2: Stress sweep data showing variation in loss modulus for flaxseed fortified peat nut spread samples (F10, F20, F30) and control sample at 20 ºC.

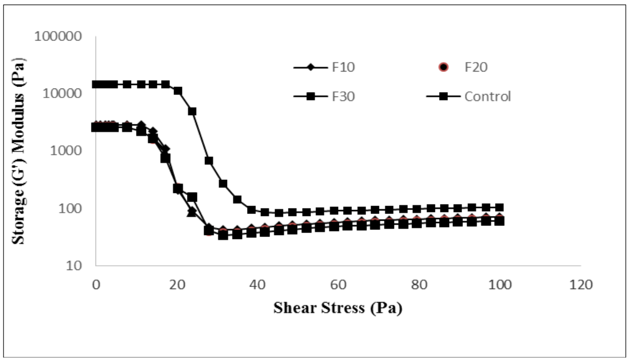

Fig 3: Stress sweep data showing variation in storage modulus for flaxseed fortified peat nut spread samples (F10, F20 and F30) and control sample at 35 ºC.

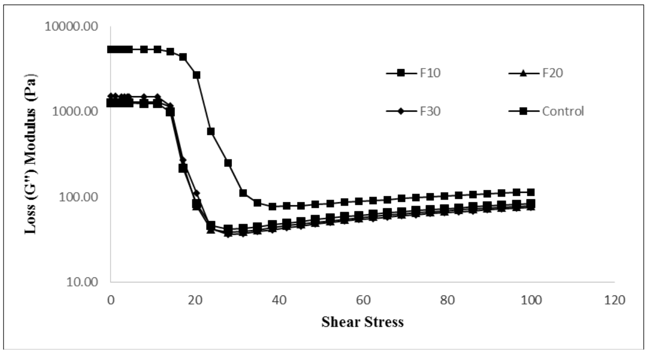

Fig 4: Stress sweep data showing variation in loss modulus for flaxseed fortified peat nut spread samples (F10, F20 and F30) and control sample at 35 ºC.

Frequency Sweep Test

Frequency sweep test of flaxseed fortified peanut paste was conducted at 20 and 35 C. It was found that magnitude of storage modulus (G') and loss modulus (G") increased marginally with the frequency at both temperatures. Figure 5 & 6 indicated that G', G", of peanut paste samples with different level of flaxseed fortification changed with frequency. Based on Figure 5 and 6, it is evident that with the increasing amount of flaxseed paste, peanut butter's G' decreased. The G" kept also declined while adding flaxseed paste. It indicated a certain amount of oil and mucilage's from flaxseed had decreased the elastic as well as viscous components of peanut paste and there by weakening the strength of peanut paste system. The decreased strength of peanut paste system fortified with flaxseed is result of oiling off from the flaxseed, which is evident form the results of textural properties test. Frequency sweep test also indicated that G' was larger than G" in all samples of peanut paste fortified with flaxseed, which showed that peanut paste fortified with flaxseed system was the viscoelastic system and elasticity had a major governing role.

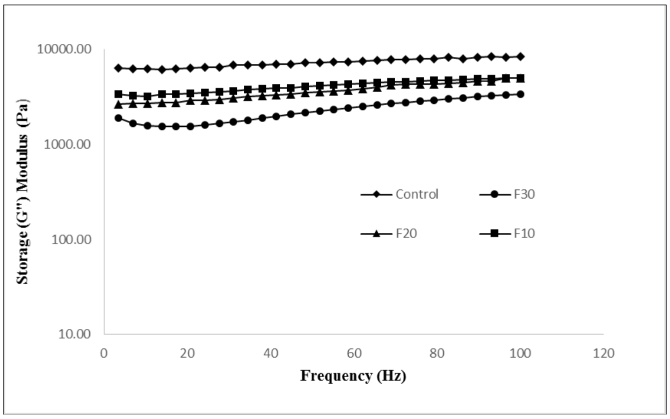

Fig 5: Frequency sweep data showing variation in loss modulus for flaxseed fortified peat nut spread samples (F10, F20 and F30) and control sample at 20 ºC.

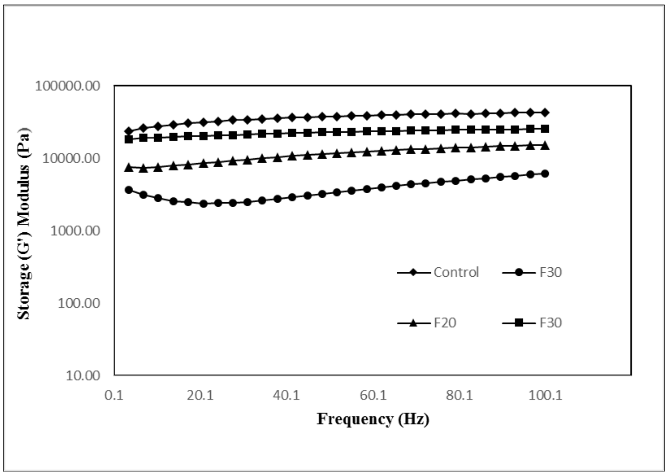

Fig 6: Frequency sweep data showing variation in storage modulus for flaxseed fortified peat nut spread samples (F10, F20 and F30) and control sample at 20 ºC.

Applicability of Hershey Buckley Model

Herschel Bulkley model elucidates the rheological behavior of peanut paste samples fortified with different levels of flaxseed paste. Table 2 states about the Yield stress as well as the model coefficients (K and n) in conjunction with statistical parameters (coefficient of determination).

Conferring to Table 2, rooted upon Herschel Buckley model, the peanut fortified with flaxseed paste flow curve were having R^2 above 0.96 to 0.99. This indicated that rheological type of peanut paste obeys Herschel Buckley's model. Yield stress is the minimum stress needed for peanut paste to flow and the main factor that effects the spread-ability of peanut paste. If yield stress is high, it results in increase in hardness of peanut paste and decrease its spread-ability, and if yield stress is less, it will improve the mobility and spread-ability of peanut butter. While yield stress is much less, it will make the peanut paste fluid and hence results in poor conformity and spread-ability. Table 2 indicates that peanut paste had high yield stress when it doesn't have flaxseed paste and the addition of flaxseed paste resulted in decrease in yield stress. This was principally as a result of flaxseed pate had oil and mucilage's that lowered the viscosity of peanut paste and improved the mobility among the peanut particles. When flaxseed was added, the consistency index increased up to 20% concentration. It indicates that flaxseed can lower the pseudo plastic degree of peanut paste (shear-thinning effect). Pseudo plastic behavior is the phenomenon of influencing the object to be tested with the increasing shearing rate that changes the direction and organization of its inner particles', resulting in the breakage of its network structure, which decreases its viscosity.

Table 2: Parameters obtained by fitting Herschel Buckley's model at 35 ºC.

Samples	Yield Stress	K (Ps.s)	n	R^2
Control	5.46^a±0.29	16.06±2.31	1.79^a ±0.17	0.96
F10	4.85^b±0.18	4.30^b ±1.23	1.49^a ±0.35	0.99
F20	4.80^b ±0.26	4.3^b ±0.87	1.42^a ±1.34	0.99
F30	3.96^c±0.18	3.78^b ±1.23	1.21^a ±1.17	0.99

Effect of flaxseed fortification on textural properties of peanut butter

Peanut butter is a type of spread having both elastic as well as viscous properties. Hardness (Firmness) and consistency are the two important indicators determining its spread-ability and texture [24]. Hardness influences the force required to spread the peanut butter. With increase in hardness, It becomes difficult to spread the peanut butter on food On the contrary, when hardness is too less, peanut butter will be soft and will collapse or flow easily. Another desired textural characteristic of peanut butter is stickiness which is primarily influenced by its adhesiveness. Stickiness allows peanut butter to adhere on the food surface better. However, too much stickiness makes the peanut butter adhere to smudge tool and difficult to flow in mouth, making it hard to chew and swallow. Table 3 shows that peanut butter had high hardness and stickiness without addition of flax seeds. It adhered to the smudge tool easily and was also hard to spread thus showing poor spreading property. Abegaz and Kerr [25] reported that for the viscoelastic materials, an increase in hardness may occur from the greater elastic or viscous component. In this case also in control samples the rheological studies showed the highest storage modulus.

Table 3: Textural Parameters of flaxseed fortified peanut butter samples along with control sample.

Samples	Hardness(N)	Cohesiveness/Stickiness (N)
Control	205.28^a ±3.08	-432.43^a ±3.89
F10	184.79^b ±2.72	-392.43^b ±2.16
F20	167.20^c ±2.41	-374.13^c ±3.17
F30	151.74^d ±2.78	-354.19^d ±2.89

Note: Different letters carried by the mean (±standard deviation)in the same line refers to significant difference (p<0.01).

With increasing addition of concentration of flaxseed, hardness as well as stickiness showed a declining trend. The declining trend was due to addition of flaxseed made peanut paste texture softer, thereby decreased the applied force to be overcome. Not only addition of flaxseed softened the peanut paste but also maintained the adhesive property in a suitable range which was helpful in enhancing the spread ability. This matched the rheological test results which showed that addition of flaxseed decreased the yield stress and the consistency index of peanut paste.

Effect of flaxseed fortification on color of peanut butter:

CIELAB system was used for the measurement of colour parameters (L*, a*,b* values). The L* quantifies the lightness and ranges from black (L*=0) to white (L*=100); a* and b* are chromaticity coordinates. The colour attribute of the formulated spreads are presented in Table 4.

Table 4: Color parameters of flaxseed fortified peanut butter samples along with control sample.

Samples	L*	a*	b*
Control	54.93^a ±0.17	11.12^a ±0.09	35.59^a ±0.13
F10	46.52^b ±0.57	8.22^b ±0.03	27.50^b ±0.05
F20	40.38^c ±0.74	7.74^c ±0.14	24.03^c ±0.10
F30	34.65^d ±0.67	7.44^c ±0.02	21.44^d ±0.11

Note: Different letters carried by the mean (±standard deviation) in the same line refers to significant difference (p<0.01).

According to the results there was a decreasing trend in L* value was significantly (p value <0.01) with increase in flaxseed concentration. The samples turned intensely brown from the yellow color due the presence of brown colored chromophore pigments present in the flaxseed. More the concentration of flaxseed in the sample more-light will be absorbed by chromophore pigments and darker will be color of the samples [6].

Conclusion

Steady state rheological properties showed that peanut paste fortified with flaxseed was pseudo plastic. The rheological properties of all the samples fortified with flaxseed are conformed to the Herschel Buckley model. Addition of flaxseed paste can decrease the yield stress and hardness of peanut paste. It is evident from the dynamic rheological properties that flaxseed paste decreases the storage modulus, loss modulus in all the samples, which helps in enhancing the fluidity of peanut paste and thereby creating the liquid like properties of peanut paste more apparent. The analysis of textural properties reveled that flaxseed paste has the potential to decrease the hardness and cohesiveness of peanut butter, thereby taming the shortcomings of reduced spread ability and too resilient adhesion of normal peanut paste.

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