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ORIGINAL ARTICLE

Incorporation of pea peel powder: Effect on dough quality, physical properties and shelf life of the cookies

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Abstract The present study was conducted to utilize the commonly discarded pea processing industrial waste (pea pods) for the development of popularly consumed food as cookies. Sweet and salted cookies were prepared by substituting refined and whole wheat flour with pea pod powder at the levels of 5%, 10%, 15% and 20%. The effect of incorporation of pea pod powder on pasting properties of flour, dough characteristics, physical properties and organoleptic attributes of cookies was studied. With the increase in the level of incorporation of pea peel to wheat flour, water absorption capacity increases by 11–14% and dough development time by 1.8 to 2.3 min but decreased final viscosity by 39–49% and dough stability time by 3 min. Addition of pea peel powder to wheat flour improved the physical properties of cookies. On the basis of organoleptic score and physical properties, 10% substitution of whole wheat flour with pea peel powder was accepted. Addition of 10% pea peel powder to the cookies increased fiber content by 49%, insoluble fiber by 118% and soluble fiber by 77.5%. The optimized sweet and salty cookies were packed in different packaging materials and were stored at ambient conditions for 4 months. Cookies packed in aluminum laminate had shelf life beyond 4 months than other packaging materials. The cookies were organoleptically acceptable among the consumers and were rich in fiber. Thus, pea processing waste could be utilized as an ingredient for the development of nutritionally enriched cheap food products.

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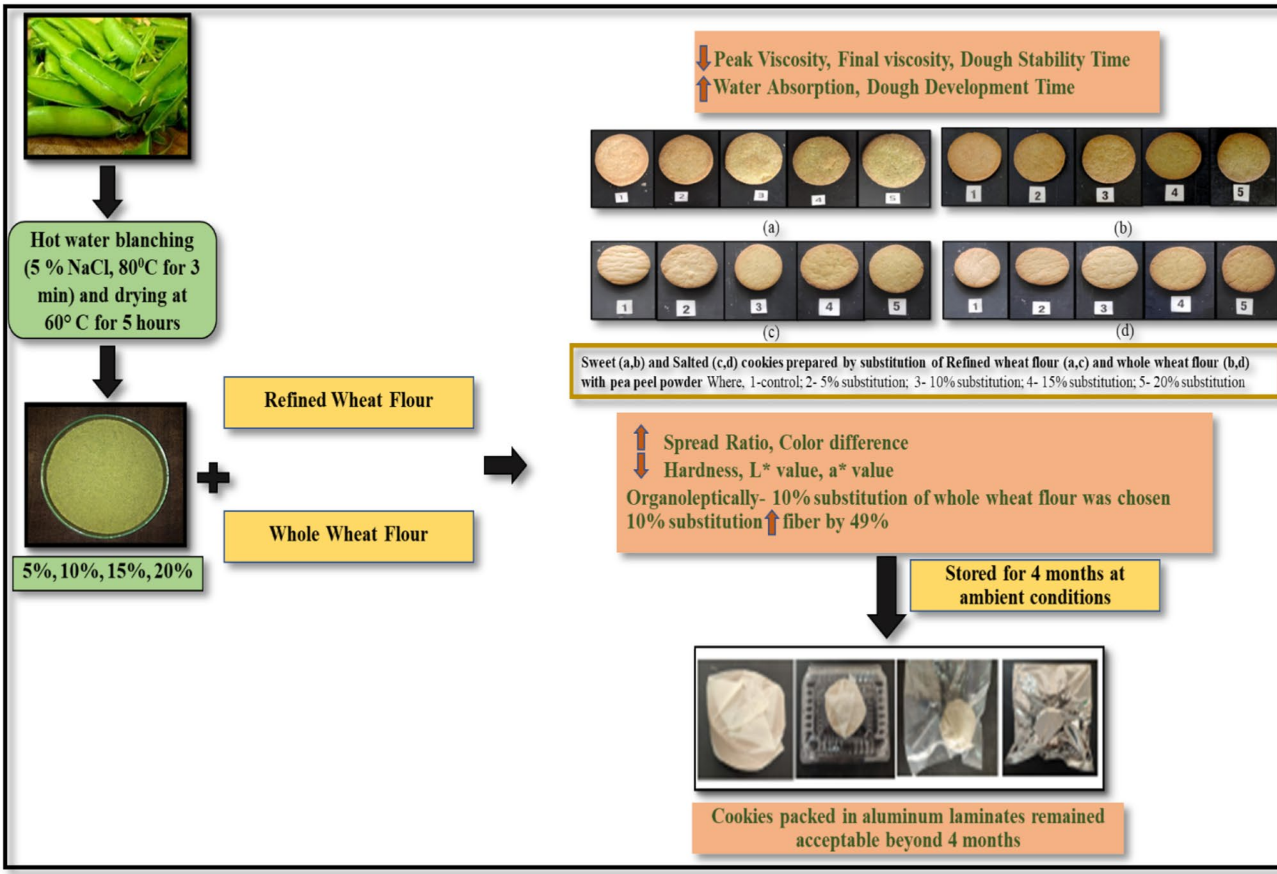
Graphical Abstract



Keywords Wheat flour · Pea pod · Fiber · Pasting viscosities · Water absorption · Packaging material

Introduction

Peas (Pisum Sativum L.) have been part of the human diet due to their availability at low cost and high nutritional value. The peas consist of the pea beans which are the seeds of the plant and the pea pod that is the sheath that protect the seeds. The bean is generally consumed as food and non-GMO status, less allergenicity, and significant nutrient density of peas meets the dietary needs of approximately 800–900 million malnourished individuals worldwide (Garg et al. 2014). However, the pea pod is usually discarded as wastage or animal feed. As far as the wastage is concerned, more than 1 million tons of pea pod waste is discarded annually as 35–45% of the total pea weight is due to pea pods (fresh wet basis) (Sharma et al. 2015). After collecting the peas, enormous amount of pea pods (peel) are left that have been depreciated till now. Pea pods and small shelled peas have been discarded by frozen and canning pea processing industries during the cleaning, grading and processing operations.

The exploitation of food industries wastes as by-products for the production of supplements with high nutritional value or food additives has gained immense interest. The foremost advantage of industrial waste is that it is available at zero cost and in huge quantities (Upasana and Vinay 2018). Pea pod waste has been exploited for cellulolytic enzyme production and as a feed for goats and pigs (Wadhwa et al.2006). Being nutritionally enriched, particularly in fiber and iron content pea pods have largely attained attention to be used in food products. Pea pods mainly consist of 55–60% of dietary fibers of which 54% is the insoluble fiber that mainly consists of 26% of cellulose, 20% of hemicelluloses and 3.92% lignin content, and 4% of soluble fiber on dry basis is present that characterizes mainly pectin and pectic substances (Kumari and Deka, 2021, Wadhwa et al.2006). The dried pea pod powder contains 0.43% fat, 5% ash content, 14.88% protein and 61.43% of total carbohydrates and provides 309.11 kcal energy content (Garg 2015). Furthermore, the changing view and perception about food is highly influencing the consuming patterns that challenges the food researchers to develop nutritious product by substituting the conventionally used ingredients. Also, the disposal of by-products of agricultural produce is one of the major challenges for environment protection. The incorporation of fruit and vegetable processing industrial waste into commonly consumed foods could be employed to address challenges of waste disposal. Thus, pea pod powder being enriched source of dietary fiber could be exploited to supplement fiber in certain cereal products (bakery products) by substituting the wheat flour to boost their nutritive value. Thereby, present study was planned to determine the effect of addition of pea peel powder on the dough rheological properties, to optimize the incorporation levels of pea pods in the whole wheat flour and refined wheat flour cookies and to know the effect of storage and packaging material on moisture content, water activity, lipid peroxidation, texture and acceptability of cookies.

Materials and methods

Raw material

Refined wheat flour was purchased from local market and whole wheat flour (HD 3086) was procured from Krishna flour mills near Punjab Agricultural University, Ludhiana. Pea peels were procured from local food vendors, sorted, washed and blanched with 5% sodium chloride at 80˚C for 3 min. Blanched pea peels were immediately dipped in cold water and dried in laboratory tray drier (Narang Scientific Works Pvt. Ltd., New Delhi) at 60 °C for 5 h followed by grinding and packing in polythene bags. Powder was stored under refrigeration conditions (4 ± 1 °C) till use. For the preparation of cookies, refined sugar, shortening (Gagan Vanaspatti ghee) and sodium chloride (Tata Salt) was purchased from local market. Sodium bicarbonate used in study was purchased form Molychem chemicals.

Proximate composition

The proximate composition such as moisture, ash, fat, protein, crude fiber and carbohydrate content of whole wheat four, refined wheat flour, pea peel powder and of optimized cookies was determined by following the standard method of AACC (2000). The soluble and insoluble dietary fiber in cookies was determined using a Megazyme total dietary fiber kit by following the enzymatic gravimetric method AACC (2010) method 32–07.01.

Preparation of composite flour

Whole wheat flour and refined wheat flours were used for the preparation of control samples. The composite flour blends were prepared by substituting the whole wheat flour and refined wheat flour with 5%, 10%, 15%, 20% of pea peel powder.

Pasting properties and dough characteristics of composite flour

The pasting behavior of control and composite flour was studied with a Rapid Visco Analyzer (RVA starch master 2, Newport Scientific, Narranbeen, Australia). The pasting profile was recorded using 3.5 g sample (on 14% moisture basis) and 24.5 ml distilled water (Yadav et al. 2010). Initially, the slurry was heated at 50° C with continuous stirring for 10 s and held at the same temperature for 1 min. the heating temperature then increased to 95° C for 7 min and held for 5 min and finally cooled to 50° C.

Dough characteristics of composite flour were determined by using doughLAB (doughLAB 500, Perten Instruments, Sydney, Australia). For the analysis, take 300 g of flour sample at 14% moisture content and enters the estimated water absorption of the flour on the system. DoughLAB automatically dispenses the required amount of water and mixing continues for 10 min at the speed of 61 rpm. DoughLAB calculates correct water absorption (%), dough development time (minutes), stability time (minutes) and peak energy to reach a peak of 500 FU (Farinograph Units).

Preparation of dough

Sweet cookie dough was prepared by following the standardized recipe given by given by Rai et al. (2014), and in salted cookies the amount of salt and sugar content was decided on the basis of preliminary sensory analyses. For the preparation of sweet cookies, flour sample (100 g), sugar (58 g), shortening (28 g), sodium bicarbonate (1 g), sodium chloride (0.9 g), dextrose solution (13.8 ml, 8.9 g glucose in 150 ml water) was taken whereas, salted cookies were prepared by reducing sugar to 40 g and by adding 3 g sodium chloride. Cookie dough was prepared by using whole wheat flour, refined wheat flour and composite flour blends.

For the preparation of dough initially creaming (mixing of sugar and shortening) was done at low speed for 2 min using laboratory mixer (National Manufacturing Company, Colorado, USA). All the dry ingredients (flour, salt, baking powder) were sieved earlier for the uniform mixing and then added to the mixer bowl and subjected to low-speed mixing for 1 min. Add dextrose solution and desired level of water during continuous mixing until homogenized dough is prepared.

Preparation of cookies

Cookies were prepared according to the AACC (2000) approved method 10–50 D (wire cut method). Sweet and salted cookies were prepared using whole wheat flour, refined wheat flour and composite flour blends. A firm dough was made by mixing the ingredients using laboratory mixer (National Manufacturing Company, Colorado, USA) utilizing desired level of water. The dough was then sheeted manually using sheeting board (thickness 5 mm) and rolling pin and then cut into circular shape (5.5 cm diameter) with cutter and baked at 204° C for 10 min. Cookies were cooled at room temperature for 30 min.

Dimensional characteristics

After cooling the cookies, the dimensional characteristics as thickness, width and spread ratio were evaluated according to method described by AACC (2000) method 10–52 (Baking quality of cookie flour- micro method). The thickness (cm) and width (cm) of 5 cookies was measured using vernier caliper. Then, the spread ratio of cookies was calculated by following the formula:

Spread Ratio = Average width of 5 cookies/ Average thickness of 5 cookies.

Texture

The texture (hardness) of the cookies was determined using Stable Microsystem Texture Analyzer (Model: TA-H di England). The texture analyzer calibrated with 250 kg load cell and probe three-point bending rig was used with pre-test speed, test speed and protest speeds of 1 mm/s, 1 mm/s and 1 mm/s, respectively and the 5 mm gap between probe and sample was maintained (Kaur et al. 2017).

Color value

The color values of cookies were determined using Hunter Lab Colorimeter (CR-300 Minolta Camera, Japan). Before using, calibrate the colorimeter with white tile and black tile. The change in colour was calculated by comparing L*, a* and b* values of control cookies with the cookies prepared using composite flour blends.

$$\Delta E = \sqrt{(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2}$$

where, L_1, a_1, b_1- L*, a*, b* value of control cookies prepared using whole wheat flour and refined wheat flour, L_2, a_2, b_2- L*, a*, b* value of cookies prepared by using composite flour blends.

Sensory evaluation

Sensory evaluation of all the cookies was done for different sensory attributes like appearance, flavor, texture and overall acceptability by semi-trained panel of 18 members (including faculty and post-graduate students) on the basis of 9-point hedonic scale (from liked extremely (9) to disliked extremely (1)) (Linda et al. 1991).

Shelf-life evaluation of cookies

The selected cookies were packed in four different packages (A-Butter paper; B-Butter paper + Polyethylene terephthalate (PET) box; C-Butter paper + Low Density Polyethylene (LDPE) pouch; D-Butter paper + Aluminum laminate) and stored under ambient conditions from mid-June to mid-September (for a period of 4 months). The thickness of butter paper, PET box, LDPE pouch and Aluminum laminate was measured as 0.09 mm, 2 mm, 0.08 mm and 3 mm respectively using vernier caliper (Thetis Electronic Digital Caliper). During storage changes in moisture content, water activity, free fatty acid, peroxide value, texture, color value and overall acceptability (hedonic scale rating) were recorded at the interval of 15 days.

`Moisture content of cookies was determined as per the AACC (2010) air oven (44–15.02) method and water activity was measured using hygrolab water activity meter (Pawkit, Decagon Devices, Inc., Pulluman, Washington, USA). For the determination of free fatty acids, standard procedure given by AOAC (2000) was followed. Free fatty acids were extracted using benzene and then extract was further dissolved in benzene and titrated against 0.02 N potassium hydroxide till light pink colour appeared. Peroxide value was determined by following iodometric titration method (AOCS, 2003). To the 5 g of sample, 50 ml of chloroform was added and then mixture was shaken using mechanical shaker for 1 h. Filter the contents and transfer 20 ml of filtrate to iodine flask, add 30 ml of acetic acid and 1 ml of saturated potassium iodide solution. Keep it in dark for 30 min. Add 50 ml of distilled water and titrate against 0.02 N sodium thiosulphate solution using 1% starch as an indicator till colorless end point.

Peroxide value (meqO_2/Kg) = Titre value*Normality of sodium thiosulphate*1000/Weight of fat.

The texture (hardness) of the cookies upon storage was determined using Stable Microsystem Texture Analyzer (Model: TA-H di England). Overall acceptability of cookies was evaluated on the basis of 9-point hedonic scale.

Statistical analysis

The results in triplicates were statistically analyzed using factorial design in CRD (Completely Randomised Design) using CPCS-1 software (Gomez and Gomez, 2010). The p-values were calculated and the results were expressed as CD (Critical Difference) at 5% level of significance. Data was also analyzed using post-hoc test (Duncan's Multiple range Test) in SPSS software (IBM, SPSS Inc., USA).

Results and discussion

Proximate composition of raw material

Pea peel powder contained significantly ($p \leq 0.05$) high amount of ash (12.29%) and crude fiber (8.67%) content in comparison to whole wheat flour (2.89% ash and 1.80% crude fiber content) and refined wheat flour (0.54% ash and 0.29% crude fiber content). Due to the presence of bran in whole wheat flour, it has high fat (1.72%) than refined wheat flour (0.98%) and pea peel powder (1.14%). Pea peel powder has lower protein content (11.86%) than whole wheat flour (13.06%). Higher ash and crude fiber content of pea peel powder results in low relative concentration of carbohydrates (66.04%) in pea peel powder than whole wheat flour (80.53%) and refined wheat flour (85.9%) (supplementary Table1). The proximate composition of pea peel powder was somewhat different from that reported by Garg (2015) and Belghith-Fendri et al.(2016a). Garg (2015) found that pea peel powder constituted 0.43% fat content, 5% ash content, 14.88% protein content and 61.43% of total carbohydrates of which 7.786% is crude fibre content and provides 309.11 kcal energy. Also, Belghith-Fendri et al. (2016a), reported 13.37% of protein content and 1.06% of fat content in pea pods. Mateos-Aparicio et al.(2010) reported 10.8% protein content, 1.3% fat content and 6.6% ash content in pea pods. Ash content of pea peel powder in the present study was higher because of blanching of pea peel with sodium chloride. Moreover, the difference in proximate composition could be attributed to the difference in growing conditions of peas, variety of peas, mode of cultivation of peas as well as on the method of processing and place from where the pea pods have been procured (Wang et al. 2010).

Pasting properties of composite flour substituted by pea peel powder

The effect of using composite flour blends on various parameters such as pasting temperature, peak viscosity (the maximum hot paste viscosity), holding viscosity (the minimum hot paste viscosity between peak and final viscosity), breakdown viscosity (the difference between peak and holding viscosity), final viscosity (the viscosity at the end during the holding temperature after cooling at 50° C) and setback viscosity (the difference between final and holding viscosity) were recorded. All the parameters were negatively correlated with the addition of pea peel powder to wheat flour. The paste temperature slightly decreased from 94.7 to 93.1° C and 92.9 to 91.9° C with increase in the incorporation level

Table 1 Pasting properties and dough characteristics of refined and whole wheat flour substituted by pea peel powder

Pasting properties										
Parameters	Refined wheat flour (RWF)					Whole wheat flour (WWF)				
	Control	5%	10%	15%	20%	Control	5%	10%	15%	20%
Paste temp (°C)	94.7 ± 0.01^a	94.4 ± 0.01^b	93.6 ± 0.01^c	93.6 ± 0.02^c	93.1 ± 0.01^d	92.9 ± 0.01^a	92.7 ± 0.01^b	92.4 ± 0.03^c	92.1 ± 0.01^c	91.9 ± 0.02^d
Peak viscosity (cP)	1351 ± 15.2^a	1293 ± 17.2^b	1158 ± 11.5^c	1096 ± 11.0^d	839 ± 13.25^e	1101 ± 8.12^a	951 ± 9.63^b	808 ± 7.41^c	724 ± 12.20^d	603 ± 10.87^e
Hold viscosity (cP)	934 ± 9.54^a	832 ± 15.50^b	712 ± 13.4^c	667 ± 14.71^d	436 ± 11.23^e	696 ± 8.10^a	503 ± 9.42^b	414 ± 11.17^c	346 ± 12.20^d	285 ± 10.56^e
Final viscosity (cP)	1756 ± 11.2^a	$1666 \pm 14.^b$	1415 ± 15.9^c	1349 ± 12.2^d	1066 ± 10.54^e	1476 ± 15.3^a	1242 ± 12.57^b	1031 ± 13.24^c	896 ± 12.33^d	753 ± 10.81^e
Breakdown viscosity (cP)	417 ± 3.5^a	461 ± 2.7^b	446 ± 1.4^c	429 ± 1.0^d	403 ± 1.2^e	405 ± 5.2^a	448 ± 4.7^b	394 ± 3.5^c	378 ± 2.1^d	318 ± 1.7^e
Set back viscosity (cP)	405 ± 5.20^a	373 ± 7.71^b	257 ± 5.48^c	253 ± 4.56^c	227 ± 8.64^d	375 ± 9.54^a	297 ± 8.23^b	223 ± 6.41^c	172 ± 5.32^d	150 ± 4.41^e
Dough characteristics										
Water absorption (%)	63.00 ± 1.1^a	65.90 ± 1.7^b	68.00 ± 2.1^c	71.40 ± 1.7^d	72.70 ± 1.1^d	66.60 ± 1.2^a	67.40 ± 1.5^a	70.10 ± 1.7^b	72.80 ± 1.4^c	74.06 ± 1.2^d
Stability (minutes)	6.4 ± 0.08^e	5.1 ± 0.05^d	4.8 ± 0.03^c	3.7 ± 0.08^b	3.1 ± 0.1^a	4.2 ± 0.7^e	3.9 ± 0.9^d	2.6 ± 0.6^c	1.9 ± 0.7^b	1.2 ± 0.5^a
Dough development Time (minutes)	6.7 ± 0.1^a	7.1 ± 0.2^b	7.5 ± 0.1^c	7.9 ± 0.2^d	8.5 ± 0.1^e	6.9 ± 0.8^a	7.4 ± 0.4^b	7.8 ± 0.9^c	8.5 ± 0.7^d	9.2 ± 0.5^e
Peak energy (Wh/kg)	9.2 ± 1.4^a	10.3 ± 1.3^a	12.1 ± 0.9^b	12.5 ± 0.7^b	12.7 ± 1.1^b	13.8 ± 1.5^a	14.3 ± 1.1^a	15.5 ± 1.9^b	19.5 ± 1.3^c	21.8 ± 1.5^d

Mean value ± standard deviation of three replicates, $^{(a-e)}$ means significantly different ($p \leq 0.05$) column wise of pea peel powder from 0 to 20% in refined and whole wheat flour respectively.

With the increment of pea peel powder, the breakdown value first increased with 5% replacement of refined wheat flour and whole wheat flour from 417 to 461 cP and 405 cP to 448 cP respectively, and then decreased to 403 cP and 318 cP when the blend contained 20% pea peel powder and 80% of refined and whole wheat flour respectively. Similarly, Liu et al.(2019) observed the increase in the breakdown viscosity upon addition of 3% wheat bran as a source of dietary fiber. However, as the incorporation level was increased up to 12% there was significant reduction in breakdown viscosity by 22%. The peak viscosity decreased with the increase in incorporation level of pea peel powder. Peak viscosity is related to the capacity of starch to absorb water and swell upon heating, that indicates the maximum swelling of the starch granules. With the increment in pea peel powder peak viscosity intensely decreased which may be due to the competition for water between pea peel powder fibers and starch granules. Also, the significant ($p \leq 0.05$) decrease was found in final viscosity. Final viscosity is dependent on amylose and amylopectin content and their ratio (Tester et al.1990). The addition of pea peel powder decreased final viscosity as due to increase in fiber content, the relative content of starch in the sample decreased that caused decline in final viscosity as presented in Table 1. Also, the higher water binding capacity of insoluble fiber than starch, reduces the water availability for absorption by amylopectin that provides resistance to the swelling of starch granule and forms completely sticky end product (Lei et al.2021). Peak and final viscosity of whole wheat flour substituted by pea peel powder was in the range of 1101 to 603 cP and 1476 to 753 cP respectively, that was lower than that of refined wheat flour substituted by pea peel powder (peak viscosity-1351 to 839 cP and final viscosity- 1756 to 1066 cP). The addition of 10% insoluble tomato fiber to the wheat flour significantly decreased the peak viscosity from 1285.56 to 450.445 cP and final viscosity from 1424.63 to 514.11 cP but increased pasting temperature from 86.2 to 90.75° C (Chouaibi et al.2018). The setback viscosity indicates the extent of aging due to the rearrangement of starch granules and recrystallization of amylose molecules upon cooling. Higher water absorption of fiber permits the rearrangement of water molecules in dough, so its availability for retrogradation reduces and inhibit the aging of starch to a certain extent, consequently the setback value gradually decreased from 405 to 227 cP and 375 cP to 150 cP upon replacement of refined and whole wheat flour respectively, with 20% of pea peel powder. The results are in accordance with Yadav et al.(2010) and Liu et al.(2019) who reported similar effect on rheological properties of dough upon addition of wheat bran to flour. The addition of 10% insoluble dietary fiber from wheat bran to wheat flour decreased peak viscosity, final viscosity and set back viscosity by 39.94%, 70.51% and 65.47%, respectively (Lei et al.2021).

Dough characteristics of composite flour substituted by pea peel powder

Incorporation of pea peel powder had significant ($p \leq 0.05$) effect on dough characteristics of refined wheat flour and whole wheat flour used to prepare cookies. Water absorption rate of composite flour blends significantly ($p \leq 0.05$) increased with the increment in the level of incorporation of pea peel powder. The addition of pea peel powder increased fiber content resulting in more water holding during dough formation which might be due to high water hydration capacity of fiber. Water absorption depends upon the number of hydroxyl groups of fiber which forms hydrogen bonding with water, thereby increases the water absorption capacity of the flour. The average increase in the water absorption of pea peel powder incorporated flour was 14% in refined wheat flour and 11.2% in whole wheat flour. Liu et al. (2019) found 14.93% increase in water absorption capacity of wheat flour to which 12% bran was added. Similarly, Chouaibi et al. (2018) reported significant increase in water absorption upon addition of insoluble tomato fiber to wheat flour. Dough development time is the time taken by the dough to reach maximum consistency. The incorporation of pea peel powder to refined and whole wheat flour significantly increased dough development time from 6.7 to 8.5 min and 6.9 to 9.4 min, respectively that showed slower dehydration at higher level of pea peel powder. The results are in consistent with Yadav et al. (2010), Huang et al. (2016) and Chouaibi et al. (2018). The addition of 12% of fenugreek fiber to the wheat flour increased water absorption by 23.5% and dough development time by 19 min which could be due to the high-water holding capacity of fenugreek fiber (Huang et al. 2016). The increase in dough development time is due to the impairment of gluten network brought by high fiber content of the pea peel powder which required more time for dough to achieve optimal state. During mixing, dough releases water to the dough matrix that reduces the dough consistency thereby reduces dough development time (Majzoobi et al. 2011) but, the fiber present in pea peel powder absorbed the water released by mixing dough therefore increased the dough development time. Dough stability time is the time difference between arrival time and departure time. Higher dough stability time indicates higher flour strength (Chouaibi et al. 2018). The addition of non-gluten flour weakens the gluten network resulting in dough weakening and thereby addition of pea peel powder significantly

Table 2 Physical properties of cookies prepared by incorporation of pea peel powder

Parameters	Cookies	Refined wheat flour (RWF)					Whole wheat flour (WWF)				
		Control	5%	10%	15%	20%	Control	5%	10%	15%	20%
Thickness (cm)	Sweet	9.36 ± 0.10^{d}	9.22 ± 0.06^{c}	9.14 ± 0.07^{b}	9.11 ± 0.08^{b}	8.99 ± 0.05^{a}	8.91 ± 0.07^{d}	8.79 ± 0.07^{c}	8.71 ± 0.09^{b}	8.63 ± 0.06^{b}	8.52 ± 0.09^{a}
	Salty	9.13 ± 0.04^{c}	9.10 ± 0.03^{c}	9.06 ± 0.04^{b}	9.01 ± 0.04^{a}	9.0 ± 0.03^{a}	9.01 ± 0.05^{e}	8.89 ± 0.07^{d}	8.81 ± 0.06^{c}	8.74 ± 0.05^{b}	8.20 ± 0.12^{a}
Width (cm)	Sweet	53.64 ± 0.19^{a}	54.34 ± 0.21^{b}	55.03 ± 0.17^{c}	55.45 ± 0.25^{d}	56.54 ± 0.30^{e}	56.3 ± 0.28^{a}	56.78 ± 0.27^{b}	57.03 ± 0.19^{c}	57.38 ± 0.29^{d}	57.58 ± 0.13^{e}
	Salty	51.17 ± 0.15^{a}	51.90 ± 0.17^{b}	52.63 ± 0.22^{c}	53.82 ± 0.20^{d}	55.33 ± 0.19^{e}	54.77 ± 0.25^{a}	55.03 ± 0.16^{b}	55.51 ± 0.25^{c}	55.93 ± 0.18^{d}	56.11 ± 0.30^{d}
Spread ratio	Sweet	5.73 ± 0.19^{a}	5.88 ± 0.20^{a}	6.01 ± 0.12^{b}	6.09 ± 0.15^{b}	6.27 ± 0.11^{c}	6.31 ± 0.12^{a}	6.45 ± 0.13^{b}	6.54 ± 0.09^{b}	6.64 ± 0.09^{c}	6.75 ± 0.08^{d}
	Salty	5.61 ± 0.15^{a}	5.70 ± 0.11^{a}	5.81 ± 0.09^{b}	5.97 ± 0.15^{c}	6.14 ± 0.10^{d}	6.07 ± 0.11^{a}	6.19 ± 0.10^{b}	6.30 ± 0.19^{b}	6.39 ± 0.08^{c}	6.41 ± 0.10^{d}
Hardness (g force)	Sweet	3898.03 ± 9.10^{e}	3463.74 ± 8.11^{d}	2973.86 ± 13.53^{c}	2614.45 ± 8.74^{b}	2211.87 ± 8.71^{a}	3789.73 ± 10.91^{e}	3296.87 ± 9.45^{d}	2914.59 ± 8.22^{c}	2553.68 ± 10.39^{b}	2109.11 ± 9.22^{a}
	Salty	3711.93 ± 9.98^{e}	3247.75 ± 8.45^{d}	2821.68 ± 13.99^{c}	2508.19 ± 10.23^{b}	2030.50 ± 11.10^{a}	3657.73 ± 8.43^{e}	3155.92 ± 9.08^{d}	2754.92 ± 8.02^{c}	2434.67 ± 10.87^{b}	1951.48 ± 11.59^{a}
Color difference (ΔE)	Sweet	-	6.91 ± 0.48^{a}	12.06 ± 0.14^{b}	14.27 ± 0.34^{c}	16.40 ± 0.44^{d}	-	6.09 ± 0.34^{a}	9.02 ± 0.64^{b}	11.73 ± 0.3^{c}	12.77 ± 0.35^{d}
	Salty	-	5.85 ± 0.69^{a}	9.33 ± 0.70^{b}	15.95 ± 1.53^{c}	17.01 ± 0.88^{d}	-	4.43 ± 0.68^{a}	5.90 ± 0.23^{b}	10.09 ± 0.62^{c}	14.16 ± 0.54^{d}

Mean value ± standard deviation of three replicates, $^{(a-e)}$ means significant difference ($p \leq 0.05$) column wise

decreased dough stability time of refined and whole wheat flour from 6.4 to 3.1 min and 4.2 to 1.2 min, respectively with the increase in the level of incorporation of pea peel powder as stated in Table 1. Dough stability time decreased by 1.73 min by addition of 10% insoluble tomato fiber to wheat flour (Chouaibi et al. 2018).

Physical properties of cookies prepared by incorporation of pea peel powder

Sweet and salted cookies were prepared by using composite flour blends. Spread ratio and texture are important physical attributes of cookies. Higher spread ratio of cookie, good cracks and particular texture (neither hard, nor soft) is generally acceptable. The spread ratio plays an important role in attaining the preferred texture and shape of the cookies. As, lower spread ratio leads to thicker, and chewier cookies whereas, higher spread ratio results in flatter, and thinner cookies. Texture of the cookies varies from soft, chewy to crispy depending upon the preferability of the consumer. With the increase in the level of incorporation, there was a significant ($p \leq 0.05$) increase in the spread ratio of the wheat flour substituted cookies as shown in Table 2.

However, the cookies prepared by substituting whole wheat flour exhibited higher spread ratio (6.31 to 6.76 for sweet cookies and 6.07 to 6.41 for salty cookies) in comparison to the refined wheat flour cookies (5.73 to 6.28 for sweet cookies and 5.61 to 6.14 for salty cookies). Fiber addition hinders the gluten development resulting in development of weaker dough that has good flow thereby increases the spread ratio of cookies (Sozer et al.2014). Gluten is structural protein that is not desirable during cookie preparation but highly desirable during bread manufacturing. The results are in consistent with Kaur et al. (2017), who also reported increase in spread ratio of cookies from 5.84 to 8.01 upon replacement of wheat flour with oat flour. Also, sweet cookies have higher spread ratio than salted cookies which could be due to the melting of sugar resulting in increased dough flow and spread ratio upon baking. Panghal (2018) reported the significant effect of sugar, fat and water on quality characteristics of sugar snap cookies. Low sugar content results in more crumbly and dry cookies due to which the hardness of salty cookies is lesser as compared to sweet cookies. Increase in the level of incorporation of pea peel powder also resulted in softer cookies, which is be due to the addition of non-wheat flour that provides hindrance to the gluten development. The 100% substitution of wheat flour with oat flour reduced the hardness of cookies from 29.26 N to 19.70 N (Kaur et al.2017).

Color value of cookies prepared by incorporation of pea peel powder

Color is the quality parameter that has direct impact on the preferability of customer. Colour is used as process control parameter during baking as brown colour indicates the progression of the baking process. L* value signifies the lightness and its value ranges from 0 (black) to 100 (white), whereas a* value specifies the redness (+) and greenness (-) and b* value specifies the yellowness (+) and blueness (-). Pea peel incorporation had significant ($p \leq 0.05$) effect on color values of both sweet and salted cookies (Supplementary Fig. 1). Increase in the level of incorporation of pea peel (5% to 20%) in refined wheat flour and whole wheat flour sweet cookies significantly decreased L* value from 64.22 to 49.30 and from 59.09 to 46.00 respectively. L* value of cookies prepared by refined wheat flour was higher than whole wheat flour substituted cookies as the darker color of the cookies is because of bran in whole wheat four. Cookies prepared from refined wheat flour has a* value of 7.01 that decreased significantly ($p \leq 0.05$) to 5.39 with increase in level of incorporation of pea peel powder. The b* value of the cookies prepared using composite flour notably increased with increase in the level of incorporation of pea peel powder. Similar trend was found in salted cookies prepared from composite flour blends. The salted cookies prepared from refined wheat flour (control sample) had L* value of 66.71 and a* value of 6.28 that decreased significantly to 50.63 and 4.25, respectively whereas, the salted cookies prepared from whole wheat flour L* value of 58.26 and a* value of 7.42 that decreased significantly to 46 and 4.73, respectively upon addition of 20% of pea peel powder. The darker color of cookies is a characteristic of the Maillard reaction due to the presence of low molecular weight sugars in the formulation and the level of its addition to the recipe (Belghith-Fendri et al. 2016 b).

The total difference in color upon addition of 20% pea peel powder to refined wheat flour and whole wheat flour sweet cookies was 16.40 and 12.77, respectively whereas the total color difference in refined wheat flour and whole wheat flour substituted salted cookies was17.01 and 14.16 respectively when compared to the control sample (Table 2). However, L* value of sweet cookies was lower than salted cookies which could be due to the caramelization reactions. The addition of pea pod and broad bean pod fiber to bread reduced L* value and a* value of crust and crumb colour values (Belghith-Fendri et al. 2016b).

Sensory evaluation of cookies prepared by incorporation of pea peel powder

Sensory analysis is the objective evaluation done to find out the suitability of level of incorporation of pea peel powder in cookies. It includes the evaluation of the sensory attributes such as appearance, taste, texture, and overall acceptability of the cookies by trained, semi-trained or untrained panelists. Sensory analyses provide insight about the consumer preferences and valuable feedback about the acceptability of the new cookie formulation among people. Incorporation of pea peel powder into the cookie flour significantly ($p \leq 0.05$) effects the acceptability of cookies (Supplementary Fig. 2). It was noted that the addition of pea peel powder up to 10% improved the acceptability of cookies and further increase in the concentration adversely affected the appearance, texture, flavour and overall acceptability. Upon increase in the level of incorporation cookies become darker in colour and had aftertaste, which was less acceptable by panelists.

However, the flour used for the preparation of cookies had significant effect on the acceptability of cookies as cookies prepared by refined wheat flour were less acceptable among panelists than whole wheat flour cookies. Fiber in whole wheat flour exhibited good texture and mouthfeel to the cookies. Moreover, the sweet cookies had high overall acceptability score than salty cookies.

It is therefore concluded that, highly acceptable cookies can be prepared using whole wheat flour and 10% incorporation of pea peel powder in both sweet and salty cookies is acceptable. The obtained results were in consistent with Garg (2015) who reported maximum acceptance of jaggery biscuits by substituting 20% refined wheat flour with pea pod powder.

Proximate composition of cookies

The proximate composition of control and optimized (10% incorporation of pea peel powder) sweet and salty cookies was determined (Supplementary Table 2). A non-significant ($p \leq 0.05$) difference in protein and fat content of cookies was found. Moreover, the moisture content of optimized cookies was higher than control, owing to higher water absorption capacity of pea peel powder (Hanan et al. 2020). The value for ash content in optimized cookies increased from 1.35 to 1.98% in sweet cookies and 1.40 to 2.06% in salted cookies which is due to addition of salt during blanching of pea peel, that had significant effect on the relative concentration of carbohydrates. Crude fiber content in optimized cookies increased significantly from 0.79 to 1.53% in sweet cookies and 0.80 to 1.52% in salted cookies, which is due to higher crude fiber content of pea peel powder than whole wheat flour. Also, the increase in insoluble fiber and soluble fiber content was reported in optimized cookies from 1.43 to 3.13% and 0.4 to 0.71% respectively. Hanan et al. (2020) reported significant increase in moisture content, ash content and dietary fiber from 6.6 to 8.6%, 6.20 to 7.50% and 7.47 to 13.25% respectively upon addition of 12.5% pea pod powder in the formulation of instant soup mix.

Table 3 Effect of storage and packaging material on moisture content (%) of cookies

Cookies	Packaging material	Storage days								
		0	15	30	45	60	75	90	105	120
Control sweet	A	3.63 ± 0.11^{a}	5.45 ± 0.09^{b}	7.07 ± 0.06^{c}	8.28 ± 0.10^{d}	ND	ND	ND	ND	ND
	B	3.63 ± 0.11^{a}	4.48 ± 0.12^{b}	5.55 ± 0.08^{c}	6.30 ± 0.09^{d}	7.08 ± 0.10^{e}	8.63 ± 0.11^{f}	ND	ND	ND
	C	3.63 ± 0.11^{a}	4.17 ± 0.08^{b}	4.85 ± 0.05^{c}	5.11 ± 0.08^{d}	5.63 ± 0.05^{e}	6.09 ± 0.07^{f}	6.94 ± 0.08^{g}	7.29 ± 0.06^{h}	8.05 ± 0.10^{i}
	D	3.63 ± 0.11^{a}	3.95 ± 0.04^{b}	4.18 ± 0.09^{c}	4.88 ± 0.10^{d}	5.11 ± 0.14^{e}	5.92 ± 0.20^{f}	6.35 ± 0.11^{g}	6.95 ± 0.19^{h}	7.32 ± 0.15^{i}
Pea sweet (10%)	A	3.85 ± 0.09^{a}	5.70 ± 0.06^{b}	7.29 ± 0.09^{c}	8.68 ± 0.10^{d}	ND	ND	ND	ND	ND
	B	3.85 ± 0.09^{a}	4.81 ± 0.07^{b}	5.73 ± 0.05^{c}	6.88 ± 0.09^{d}	7.88 ± 0.13^{e}	9.05 ± 0.06^{f}	ND	ND	ND
	C	3.85 ± 0.09^{a}	4.66 ± 0.05^{b}	5.01 ± 0.07^{c}	5.72 ± 0.10^{d}	6.08 ± 0.09^{e}	6.49 ± 0.05^{f}	7.10 ± 0.11^{g}	7.72 ± 0.08^{h}	8.21 ± 0.10^{i}
	D	3.85 ± 0.09^{a}	4.28 ± 0.11^{b}	4.75 ± 0.10^{c}	5.09 ± 0.08^{d}	5.69 ± 0.07^{e}	6.10 ± 0.10^{f}	6.78 ± 0.09^{g}	7.09 ± 0.10^{h}	7.71 ± 0.08^{i}
Control sal	A	3.83 ± 0.10^{a}	5.43 ± 0.10^{b}	7.10 ± 0.09^{c}	8.60 ± 0.10^{d}	ND	ND	ND	ND	ND
	B	3.83 ± 0.10^{a}	4.85 ± 0.11^{b}	5.89 ± 0.08^{c}	6.93 ± 0.11^{d}	8.08 ± 0.07^{e}	9.31 ± 0.10^{f}	ND	ND	ND
	C	3.83 ± 0.10^{a}	4.56 ± 0.08^{b}	4.91 ± 0.15^{c}	5.68 ± 0.13^{d}	6.00 ± 0.10^{e}	6.45 ± 0.07^{f}	7.14 ± 0.05^{g}	7.80 ± 0.08^{h}	8.25 ± 0.11^{i}
	D	3.83 ± 0.10^{a}	4.25 ± 0.09^{b}	4.70 ± 0.07^{c}	5.05 ± 0.06^{d}	5.71 ± 0.09^{e}	6.13 ± 0.08^{f}	6.85 ± 0.11^{g}	7.13 ± 0.05^{h}	7.79 ± 0.08^{i}
Pea salt (10%)	A	4.05 ± 0.08^{a}	5.84 ± 0.11^{b}	7.34 ± 0.09^{c}	8.81 ± 0.08^{d}	ND	ND	ND	ND	ND
	B	4.05 ± 0.08^{a}	5.06 ± 0.09^{b}	6.00 ± 0.08^{c}	7.09 ± 0.06^{d}	8.31 ± 0.07^{e}	9.57 ± 0.09^{f}	ND	ND	ND
	C	4.05 ± 0.08^{a}	4.77 ± 0.06^{b}	5.19 ± 0.04^{c}	5.86 ± 0.08^{d}	6.16 ± 0.06^{e}	6.89 ± 0.07^{f}	7.31 ± 0.07^{g}	7.96 ± 0.08^{h}	8.42 ± 0.07^{i}
	D	4.05 ± 0.08^{a}	4.39 ± 0.09^{b}	4.85 ± 0.05^{c}	5.17 ± 0.07^{d}	5.89 ± 0.10^{e}	6.28 ± 0.05^{f}	6.97 ± 0.06^{g}	7.37 ± 0.07^{h}	7.93 ± 0.05^{i}

Mean value ± standard deviation of three replicates, $^{(a-i)}$ means significantly different ($p \leq 0.05$) column wise

Where, *A* Butter paper, *B* Butter paper + Polyethylene terephthalate (PET) box; *C* Butter paper + low density polyethylene (LDPE) pouch, *D* Butter paper + Aluminum laminate, *ND* Not detected

Shelf-life study of cookies prepared by incorporation of pea peel powder

On the basis of cookie quality and organoleptic score, sweet and salty cookies prepared by 10% substitution of whole wheat flour with pea pod powder was optimized. The optimized cookies along with control were packed in four different packaging material and stored under ambient conditions for a period of 4 months. Cookies were primarily packed in butter paper to avoid direct contact with plastic.

Effect of storage and packaging material on moisture content of cookies

Moisture content plays a major role in determining the shelf stability of food products. Table 3 showed the effect on moisture content during storage studies of prepared cookies packed in different packaging materials. During storage a significant ($p \leq 0.05$) increase was observed in the moisture content of the control cookies and optimized cookies. The increase in moisture content depends on nature of the product, packaging material and storage environment (relative humidity and temperature) (Nagi et al. 2012). Hygroscopic nature of fibers present in pea peel powder results in increase in moisture content of the cookies. Higher moisture content was observed in pea sweet cookies and pea salt cookies as compared to control cookies upon storage. Butter paper as a packaging material has low barrier properties toward water and gases so a sharp increase in moisture content was observed in cookies packed in butter paper. Cookies become soggy within the 30 days of storage. On the other hand, cookies packed in butter paper as well as LDPE showed gradual increase in moisture content during storage. Migration of water through polyethylene terephthalate (PET) box can be possible due to presence of pores during fabrication of these packages (Sahni and Shere 2017). Aluminum laminates have high barrier properties to migration of water, gases and flavors so the cookies packed in aluminum laminates showed high shelf stability during storage studies with slow absorption of moisture. Nagi et al. (2012) observed the increase in moisture content of biscuits upon storage for 3 months and also stated non-significant effect of packaging materials (high density polyethylene pouches and aluminum laminates) on increase in moisture content. Similar trend was found in the current investigation, that the cookies packed in LDPE and aluminum laminates remained acceptable up to 4 months of storage. Jan et al. (2017) and Sharma and Riar (2020) reported significant effect of packaging material (LDPE and metalized polyester polyethylene (MET-PPE) laminates) on increase in moisture content, with maximum increase in LDPE packed cookies.

Effect of storage and packaging material on water activity (a_w) of cookies

Water activity is one of the critical parameters of storage study. The optimum range of 0.4–0.6 of water activity values denotes the shelf stability of the product (Vadukapuram et al. 2014). Higher water activity value above 0.8 facilitates the microbial growth and deteriorates the product quality. However, the critical water activity value as an indicator of crispiness of cookies is 0.565 at 35° C (Carter et al. 2015). Upon storage highest average water activity value around 0.6 was recorded, this denotes that cookie were shelf stable up to 120 days with minimum loss in crispiness. Water activity of cookies packed in different packaging materials significantly ($p \leq 0.05$) increased with storage (Table 4). Increase in the moisture content during storage, consequently increases the water activity. The cookies packed in butter paper showed high water activity because butter paper has high tendency of water migration from atmosphere to food product. On the other hand, cookies secondarily packed in PET box and LDPE pouch had shelf stability up to 60 and 105 days because packaging material fabricated from plastic has low moisture migration capacity as compared to butter paper. Whereas, cookies packed in aluminum laminate showed maximum stability during storage i.e. cookies were shelf stable up to 4 months of storage. The maximum water activity value of cookies packed in aluminum laminates varied between 0.58–0.60 Similarly, Jan et al. (2017) reported increase in water activity value from 0.30 to 0.58 upon storage of cookies made from germinated Chenopodium in MET-PPE laminates for 120 days. Sharma and Riar (2020) reported similar increase in water activity of cookies made from raw and germinated minor millet flour upon storage. Water activity of cookies packed in different packaging materials was in safe limit for microbial safety.

Effect of storage and packaging material on free fatty acid (%) of cookies

Storage period as well as packaging material showed significant ($p \leq 0.05$) effect on free fatty acid content of packed cookies. Cookies packed in butter paper showed higher free fatty acid content (0.58) after 45 days of storage as presented in (Supplementary Table 3). Cookies packed in butter paper were easily prone to oxidation during storage due to poor barrier properties of butter paper to light and moisture migration. The increase in free fatty acid content of pea peel powder incorporated cookies is due to the increase in their moisture content which encourages the fat hydrolysis during storage. The cookies packed in aluminum laminate showed maximum stability up to 4 months of storage owing to its high

Table 4 Effect of storage and packaging material on water activity (a_w) of cookies

Cookies	Packaging material	Storage days								
		0	15	30	45	60	75	90	105	120
Control sweet	A	0.36 ± 0.02^{a}	0.45 ± 0.01^{b}	0.54 ± 0.01^{c}	0.63 ± 0.02^{d}	ND	ND	ND	ND	ND
	B	0.36 ± 0.02^{a}	0.43 ± 0.01^{b}	0.48 ± 0.02^{c}	0.53 ± 0.01^{d}	0.57 ± 0.02^{e}	0.64 ± 0.01^{f}	ND	ND	ND
	C	0.36 ± 0.02^{a}	0.39 ± 0.01^{b}	0.42 ± .02^{c}	0.45 ± 0.02^{d}	0.48 ± 0.01^{e}	0.51 ± 0.01^{f}	0.54 ± 0.02^{g}	0.57 ± 0.01^{h}	0.61 ± 0.01^{i}
	D	0.36 ± 0.02^{a}	0.38 ± 0.01^{a}	0.41 ± 0.02^{b}	0.43 ± 0.02^{b}	0.46 ± 0.01^{c}	0.49 ± 0.01^{c}	0.52 ± 0.02^{d}	0.55 ± 0.02^{e}	0.58 ± 0.01^{f}
Pea sweet (10%)	A	0.37 ± 0.02^{a}	0.47 ± 0.01^{b}	0.55 ± 0.01^{c}	0.64 ± 0.02^{d}	ND	ND	ND	ND	ND
	B	0.37 ± 0.02^{a}	0.43 ± 0.02^{b}	0.49 ± 0.01^{c}	0.54 ± 0.01^{d}	0.59 ± 0.02^{e}	0.65 ± 0.02^{f}	ND	ND	ND
	C	0.37 ± 0.02^{a}	0.40 ± 0.01^{b}	0.43 ± 0.01^{c}	0.46 ± 0.02^{d}	0.49 ± 0.01^{e}	0.53 ± 0.01^{f}	0.56 ± 0.01^{g}	0.59 ± 0.02^{h}	0.63 ± 0.01^{i}
	D	0.37 ± 0.02^{a}	0.39 ± 0.01^{a}	0.41 ± 0.01^{b}	0.45 ± 0.02^{c}	0.47 ± 0.01^{c}	0.50 ± 0.01^{d}	0.53 ± 0.01^{e}	0.56 ± 0.02^{f}	0.59 ± 0.01^{g}
Control salt	A	0.35 ± 0.01^{a}	0.43 ± 0.01^{b}	0.55 ± 0.01^{c}	0.64 ± 0.02^{d}	ND	ND	ND	ND	ND
	B	0.35 ± 0.01^{a}	0.41 ± 0.02^{b}	0.46 ± 0.02^{c}	0.54 ± 0.01^{d}	0.58 ± 0.02^{e}	0.64 ± 0.02^{f}	ND	ND	ND
	C	0.35 ± 0.01^{a}	0.38 ± 0.01^{b}	0.41 ± 0.02^{c}	0.44 ± 0.02^{d}	0.48 ± 0.01^{e}	0.51 ± 0.01^{f}	0.55 ± 0.02^{g}	0.58 ± 0.02^{h}	0.62 ± 0.01^{i}
	D	0.35 ± 0.01^{a}	0.37 ± 0.01^{b}	0.40 ± 0.02^{c}	0.43 ± 0.02^{d}	0.46 ± 0.01^{e}	0.49 ± 0.01^{f}	0.53 ± 0.02^{g}	0.56 ± 0.02^{h}	0.59 ± 0.01^{i}
Pea salt (10%)	A	0.38 ± 0.02^{a}	0.48 ± 0.01^{b}	0.56 ± 0.01^{c}	0.66 ± 0.02^{d}	ND	ND	ND	ND	ND
	B	0.38 ± 0.02^{a}	0.44 ± 0.02^{b}	0.49 ± 0.01^{c}	0.55 ± 0.02^{d}	0.60 ± 0.02^{e}	0.69 ± 0.02^{f}	ND	ND	ND
	C	0.38 ± 0.02^{a}	0.42 ± 0.01^{b}	0.45 ± 0.02^{c}	0.48 ± 0.02^{d}	0.51 ± 0.01^{e}	0.54 ± 0.01^{f}	0.57 ± 0.02^{g}	0.60 ± 0.02^{h}	0.64 ± 0.01^{i}
	D	0.38 ± 0.02^{a}	0.40 ± 0.01^{a}	0.43 ± 0.02^{b}	0.46 ± 0.02^{c}	0.49 ± 0.01^{d}	0.52 ± 0.01^{e}	0.54 ± 0.02^{f}	0.57 ± 0.02^{g}	0.60 ± 0.01^{h}

Mean value ± standard deviation of three replicates, $^{(a-i)}$ means significantly different ($p \leq 0.05$) column wise

Where, *A* Butter paper, *B* Butter paper + Polyethylene terephthalate (PET) box, *C* Butter paper + low density polyethylene (LDPE) pouch, *D* Butter paper + Aluminum laminate, *ND* Not detected

Table 5 Effect of storage and packaging material on peroxide value (meqO_2/kg) of cookies

Cookies	Packaging material	Storage days								
		0	15	30	45	60	75	90	105	120
Control sweet	A	1.17 ± 0.03^{a}	1.70 ± 0.09^{b}	2.32 ± 0.10^{c}	3.41 ± 0.13^{d}	ND	ND	ND	ND	ND
	B	1.17 ± 0.03^{a}	1.38 ± 0.07^{b}	1.90 ± 0.09^{c}	2.24 ± 0.10^{d}	2.79 ± 0.11^{e}	3.19 ± 0.08^{f}	ND	ND	ND
	C	1.17 ± 0.03^{a}	1.27 ± 0.05^{b}	1.39 ± 0.08^{c}	1.57 ± 0.07^{d}	1.92 ± 0.10^{e}	2.25 ± 0.07^{f}	2.47 ± 0.11^{g}	2.93 ± 0.09^{h}	3.35 ± 0.12^{i}
	D	1.17 ± 0.03^{a}	1.20 ± 0.03^{a}	1.29 ± 0.04^{b}	1.40 ± 0.06^{c}	1.63 ± 0.05^{d}	1.83 ± 0.06^{e}	2.04 ± 0.10^{f}	2.30 ± 0.08^{g}	2.71 ± 0.07^{h}
Pea sweet (10%)	A	1.15 ± 0.02^{a}	1.72 ± 0.03^{b}	2.29 ± 0.03^{c}	3.40 ± 0.03^{d}	ND	ND	ND	ND	ND
	B	1.15 ± 0.02^{a}	1.37 ± 0.03^{b}	1.81 ± 0.03^{c}	2.19 ± 0.03^{d}	2.74 ± 0.03^{e}	3.12 ± 0.03^{f}	ND	ND	ND
	C	1.15 ± 0.02^{a}	1.23 ± 0.03^{b}	1.38 ± 0.03^{c}	1.59 ± 0.03^{d}	1.91 ± 0.03^{e}	2.21 ± 0.03^{f}	2.48 ± 0.003^{g}	2.97 ± 0.005^{h}	3.32 ± 0.005^{i}
	D	1.15 ± 0.02^{a}	1.17 ± 0.03^{b}	1.25 ± 0.03^{c}	1.37 ± 0.03^{d}	1.58 ± 0.03^{e}	1.77 ± 0.03^{f}	1.99 ± 0.003^{g}	2.25 ± 0.005^{h}	2.68 ± 0.005^{i}
Control salt	A	1.19 ± 0.04^{a}	1.75 ± 0.03^{b}	2.37 ± 0.03^{c}	3.45 ± 0.03^{d}	ND	ND	ND	ND	ND
	B	1.19 ± 0.04^{a}	1.41 ± 0.03^{b}	1.96 ± 0.03^{c}	2.31 ± 0.03^{d}	2.82 ± 0.03^{e}	3.24 ± 0.03^{f}	ND	ND	ND
	C	1.19 ± 0.04^{a}	1.29 ± 0.03^{b}	1.41 ± 0.03^{c}	1.62 ± 0.03^{d}	1.96 ± 0.03^{e}	2.28 ± 0.03^{f}	2.52 ± 0.003^{g}	3.02 ± 0.005^{h}	3.40 ± 0.005^{i}
	D	1.19 ± 0.04^{a}	1.22 ± 0.03^{b}	1.31 ± 0.03^{c}	1.40 ± 0.03^{d}	1.64 ± 0.03^{e}	1.88 ± 0.03^{f}	2.08 ± 0.003^{g}	2.34 ± 0.005^{h}	2.76 ± 0.005^{i}
Pea salt (10%)	A	1.18 ± 0.02^{a}	1.75 ± 0.03^{b}	2.39 ± 0.03^{c}	3.48 ± 0.03^{d}	ND	ND	ND	ND	ND
	B	1.18 ± 0.02^{a}	1.40 ± 0.03^{b}	1.95 ± 0.03^{c}	2.32 ± 0.03^{d}	2.81 ± 0.03^{e}	3.21 ± 0.03^{f}	ND	ND	ND
	C	1.18 ± 0.02^{a}	1.28 ± 0.03^{b}	1.40 ± 0.03^{c}	1.66 ± 0.03^{d}	1.94 ± 0.03^{e}	2.25 ± 0.03^{f}	2.50 ± 0.005^{g}	2.98 ± 0.003^{h}	3.36 ± 0.005^{i}
	D	1.18 ± 0.02^{a}	1.21 ± 0.03^{b}	1.28 ± 0.03^{c}	1.43 ± 0.03^{d}	1.61 ± 0.03^{e}	1.90 ± 0.03^{f}	2.13 ± 0.003^{g}	2.38 ± 0.005^{h}	2.74 ± 0.003^{i}

Mean value ± standard deviation of three replicates, $^{(a-i)}$ means significantly different ($p \leq 0.05$) column wise

Where, *A*- Butter paper; B- Butter paper + Polyethylene terephthalate (PET) box; C- Butter paper + Low Density Polyethylene (LDPE) pouch; D-Butter paper + Aluminum Laminate; ND- Not Detected resistance to light and moisture migration. Also, incorporation of pea peel powder to whole wheat flour provides longer stability because fiber in pea peel powder compete for free water, that made less free water for oxidation reactions resulting in the less formation of free fatty acid. Food products having free fatty acid (%) above 1% develop rancid flavor and become unfit for consumption (Jan et al. 2017). In the present investigation maximum free fatty acid % of the cookies packed in different packages was 0.55% i.e., in acceptable limits. Sharma and Riar (2020) observed significant effect of packaging material on free fatty acid value of cookies upon storage for 160 days. They reported substantial increase in free fatty acid value from 0.26% to 1.67% in LDPE packed cookies in comparison to MET-PPE laminate packed cookies (0.26% to 0.89%). Nagi et al. (2012) also reported noteworthy increase in free fatty acids upon storage of biscuits prepared from defatted cereal brans for 3 months. They also observed profound effect of packaging material on free fatty acid value with maximum increase in biscuits packed in HDPE as compared to those packed in laminates which might be attributed to the protective effect of laminates to light and moisture.

Effect of storage and packaging material on peroxide value (meqO_2/Kg) of cookies

Peroxide value is the measurement of fat stability and is important parameter to determine the shelf stability. The 10–20 meqO_2/Kg peroxide value of food products indicate the rancidity of product but acceptable for consumption whereas, above 20 meqO_2/Kg it becomes unfit for consumption (Sharma and Riar 2020). Storage period as well as packaging material showed significant ($p \leq 0.05$) effect on peroxide value of cookies. Peroxide value of cookies packed in butter paper increased from 1.17 to 3.41 meqO_2/Kg in 45 days of storage whereas, the peroxide value of cookies packed in LDPE pouch and aluminum laminate increased up to 3.35 and 2.71 meqO_2/Kg respectively upon storage for 120 days as presented in Table 5. Cookies packed in butter paper, PET box were more prone to oxidation during storage due to poor barrier properties of butter paper and PET box to moisture migration. The peroxide values of control and optimized cookies packed in different packages were below the maximum desirable limit of peroxide value. Other researchers also reported increase in peroxide value of cookies upon storage for 120 days and also found noteworthy effect of packaging material on peroxide value with minimum effect on cookies packed in laminates (Jan et al. 2017, Sharma and Riar 2020).

Effect of storage and packaging material on texture (hardness) of cookies

Texture is the key parameter to assess the overall quality of end product. The effect of storage period as well as packaging material on the texture of control and optimized cookies is presented in Table 6. The hardness of cookies decreased from 3789 to 1511 g force and 3488 to 1481 g force in butter paper and PET box in 45 days and 75 days, respectively. The hardness of cookies is much affected by the moisture content, water activity. Cookies maintained their crispiness and texture below critical water activity (Carter et al. 2015). Hough et al. (2001) reported loss of crispiness in biscuits when water activity values increased from 0.43 to 0.60 during storage. Increase in moisture content and water activity results in sogginess of the cookies thereby, decreased the hardness of cookies, making them less acceptable among consumers. Cookies packed in butter paper and PET box showed higher decrease in texture owing to less resistance to water vapor transmission rate than LDPE pouch and aluminum laminates. However, the minimum decrease in hardness was observed in cookies packed in aluminum laminates upon storage for 120 days. The results are in consistent with Jan et al. (2017) who reported decrease in hardness of cookies from 44.43 to 31.02 N and 44.43 to 41.03 N in LDPE and MET-PPE laminates upon storage for 120 days. Similar results were reported by Sharma and Riar (2020) in raw and germinated millet flour cookies packed in different packages and stored for 160 days.

Effect of storage and packaging material on overall acceptability of cookies

Sensory studies of the product are important for estimating its acceptability and commercial significance. Sensory analysis of whole wheat flour and pea peel incorporated cookies as influenced by storage and packaging materials (Supplementary Table 4). Packaging material and storage period had significant ($p \leq 0.05$) effect on overall acceptability of cookies. The highest overall acceptability was observed for control cookies than optimized cookies. Upon storage, the increase in moisture content, free fatty acid content, peroxide value and decrease in hardness attributes the change in appearance, taste and texture of cookies which results in decrease in overall acceptability of cookies. The darkening of colour during storage could be due to the absorption of moisture from atmosphere and also due to presence of protein and sugars in cookies non-enzymatic browning (Maillard reaction) takes place (Jan et al. 2017). Decrease in overall acceptability of cookies packed in butter paper and PET box was more notable than LDPE pouch. The minimum overall acceptability score of 6 was considered acceptable, thus cookies packed in butter paper were acceptable upto 30 days of storage period whereas, cookies packed in PET box and LDPE pouch were acceptable for 60 and 105 days, respectively. Aluminum laminates provided longer shelf life and acceptability as compare to other packaging materials. This is attributed to the higher rate of moisture and

Table 6 Effect of storage and packaging material on texture (hardness (g force)) of cookies

Cookies	Packaging material	Storage days								
		0	15	30	45	60	75	90	105	120
Control sweet	A	3789.73 ± 10.91^{a}	3067.21 ± 9.13^{b}	2151.10 ± 8.03^{c}	1511.23 ± 13.03^{d}	ND	ND	ND	ND	ND
	B	3789.73 ± 10.91^{a}	3488.00 ± 9.39^{b}	3091.50 ± 10.71^{c}	2561.80 ± 5.32^{d}	2052.15 ± 8.13^{e}	1481 ± 9.23^{f}	ND	ND	ND
	C	3789.73 ± 10.91^{a}	3607.00 ± 10.25^{b}	3448.20 ± 9.39^{c}	3276.82 ± 7.39^{d}	2997.5 ± 11.28^{e}	2651.50 ± 9.37^{f}	2296.00 ± 10.57^{g}	2008.00 ± 11.29^{h}	1701.30 ± 8.35^{i}
	D	3789.73 ± 10.91^{a}	3698.00 ± 9.36^{b}	3505.04 ± 8.13^{c}	3325.50 ± 8.53^{d}	3181.00 ± 9.69^{e}	2867.52 ± 12.71^{f}	2537.00 ± 8.29^{g}	2297.00 ± 12.89^{h}	1985.63 ± 9.47^{i}
Pea sweet (10%)	A	2914.59 ± 8.22^{a}	2371.10 ± 10.33^{b}	1864.00 ± 9.09^{c}	1218 ± 8.48^{d}	ND	ND	ND	ND	ND
	B	2914.59 ± 8.22^{a}	2612.00 ± 9.49^{b}	2227.45 ± 9.47^{c}	1878.76 ± 8.58^{d}	1596.05 ± 9.18^{e}	1198 ± 7.38^{f}	ND	ND	ND
	C	2914.59 ± 8.22^{a}	2801.33 ± 8.28^{b}	2649.00 ± 8.12^{c}	2402.54 ± 9.28^{d}	2317.51 ± 8.38^{e}	2140.33 ± 8.49^{f}	1928.90 ± 10.28^{g}	1802.10 ± 9.78^{h}	1641.70 ± 8.45^{i}
	D	2914.59 ± 8.22^{a}	2884.32 ± 9.79^{b}	2701.10 ± 9.48^{c}	2654.60 ± 10.66^{d}	2488.95 ± 9.22^{e}	2315.70 ± 7.47^{f}	2199.32 ± 9.58^{g}	2007.5 ± 9.54^{h}	1816.00 ± 8.85^{i}
Control salt	A	3657.73 ± 9.43^{a}	2918.00 ± 11.37^{b}	2096.00 ± 7.83^{c}	1489.98 ± 6.13^{d}	ND	ND	ND	ND	ND
	B	3657.73 ± 9.43^{a}	3317.50 ± 10.32^{b}	2898.50 ± 9.37^{c}	2463.63 ± 6.42^{d}	1981.00 ± 7.16^{e}	1412 ± 7.25^{f}	ND	ND	ND
	C	3657.73 ± 9.43^{a}	3514.00 ± 10.71^{b}	3379.90 ± 8.08^{c}	3114.50 ± 9.11^{d}	2798.50 ± 7.78^{e}	2517.00 ± 10.48^{f}	2166.66 ± 9.32^{g}	1938.00 ± 7.52^{h}	1628.00 ± 6.49^{i}
	D	3657.73 ± 9.43^{a}	3584.00 ± 11.42^{b}	3417.95 ± 9.48^{c}	3307.95 ± 8.37^{d}	3097.50 ± 7.59^{e}	2817.52 ± 7.08^{f}	2497.00 ± 9.41^{g}	2168.70 ± 8.08^{h}	1869.30 ± 7.19^{i}
Pea salt (10%)	A	2754.92 ± 8.02^{a}	2118.54 ± 10.21^{b}	1581.85 ± 9.09^{c}	1158 ± 5.57^{d}	ND	ND	ND	ND	ND
	B	2754.92 ± 8.02^{a}	2388.00 ± 7.48^{b}	1985.33 ± 9.84^{c}	1704.50 ± 8.63^{d}	1496.90 ± 8.12^{e}	1084 ± 7.14^{f}	ND	ND	ND
	C	2754.92 ± 8.02^{a}	2624.10 ± 7.47^{b}	2484.67 ± 9.12^{c}	2279.50 ± 10.76^{d}	2118.33 ± 9.84^{e}	1994.65 ± 7.18^{f}	1806.45 ± 8.24^{g}	1566.00 ± 6.41^{h}	1286.50 ± 5.48^{i}
	D	2754.92 ± 8.02^{a}	2681.10 ± 10.84^{b}	2557.90 ± 9.48^{c}	2386.51 ± 8.27^{d}	2178.33 ± 6.48^{e}	2018.00 ± 7.68^{f}	1886.50 ± 9.12^{g}	1659.00 ± 5.27^{h}	1436.70 ± 6.49^{i}

Mean value ± standard deviation of three replicates$^{(a–i)}$ means significantly different ($p \leq 0.05$) column wise

Where, *A* Butter paper, *B* Butter paper + Polyethylene terephthalate (PET) box, *C* Butter paper + low density polyethylene (LDPE) pouch, D-Butter paper + Aluminum Laminate, *ND* Not detected gases entrance in butter paper followed by PET Box and then LDPE pouches resulting in sogginess of the cookies. Cookies packed in aluminum laminates were acceptable up to 4 months of storage period. Similar results were reported by Sahni and Shere (2017), Kulthe et al. (2018), Sharma and Riar (2020). Jan et al. (2017) reported that cookies packed in laminates of metallized polyester polyethylene could be stored for more than 120 days without much effect on their sensory quality due to its good barrier properties.

Thence, there was significant increase in all the parameters upon storage, but the aluminum laminates owing to low gas transmission and water vapor transmission rate leads to better shelf life of the cookies than other packaging materials.

Conclusions

The substitution of whole wheat and refined wheat flour with pea pod powder decreased its viscosity due to the competition for water between pea peel powder fibers and starch granules. Also, addition of pea peel powder led to poor gluten development thereby, decreases dough stability. As, the gluten development is not required during cookie preparation thus it improved the physical properties of cookies and resulted in softer cookies with higher spread ratio. Furthermore, refined wheat flour blends with pea pod powder exhibited better pasting properties, dough characteristics, and poor physical attributes than whole wheat flour blends. The study showed that cookies prepared using composite flour blends were rich in fiber. On the basis of organoleptic score and physical properties 10% substitution of whole wheat flour with pea peel powder was highly accepted than those prepared by substituting refined wheat flour. Packaging material had significant effect on the shelf-life of the cookies. During storage, change in moisture content, water activity and free fatty acid content was gradual in cookies packed in aluminum laminates and were acceptable beyond 4 months. Thus, utilization of food industry waste for the preparation of bakery products would not only help to combat the waste disposal issues but also would help to overcome the nutritional deficiency. Thence, pea pods could be utilized to boost the nutrition of food products instead of discarding it as animal feed.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest with respect to research, authorship and/or publication of this article.

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