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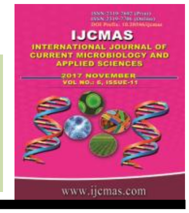

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Synergistic Effect of Polyols and Fibres on Baking, Sensory and Textural Quality of Bread with Improved Shelf Life

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A B S T R A C T

Research work has been carried out on improvement in quality of raw materials, use of additives to improve quality but work on extension of shelf life of bread is lacking. Polyols (glycerol, sorbitol and mannitol) and fibres (oat, psyllium and barley) at levels of 0-6 % were can be incorporated into breads to impart nutritive value and sensory properties. Research work has been carried to optimize and to find out the best level of polyols and fibres on the basis of quality, to find the overall acceptability of the bread on the basis of sensory evaluation by panelists and to study the shelf life of bread prepared after incorporation of polyols and fibres in suitable packaging material. Breads prepared with incorporation of polyols (glycerol, sorbitol and mannitol) and fibres (oat, psyllium and barley) at levels of 0-6 % were packed in different packaging materials (Low density Polyethylene and Polypropylene) and stored under ambient (30±1ºC) and refrigerated (4-6ºC) conditions. Breads were prepared from combination of polyols and fibres with acceptable product quality and optimum organoleptic properties. The shelf life of products was studied as periodic changes in moisture content, water activity, free fatty acid and microbial load. Moisture content and water activity were higher for bread prepared from combination of 2 % oat fibre along with 2 % glycerol, 2 % barley fibre along with 9 % sorbitol and 2 % psyllium fibre along with 9 % sorbitol as compared to control bread and it was observed that moisture content was higher in products packed in PP. Water activity was higher for products packed in PP. The breads stored well up to 10 days when packed in PP under ambient conditions and it remains unspoiled for 15 days under refrigerated conditions but it was unacceptable due to hard texture. Bread incorporated with polyols and fibres were acceptable after storage period of 10 days in Polypropylene under ambient conditions. Apart from increase in shelf life, fibres and polyols could be helpful in producing specialty foods for consumption of people suffering from diabetics furthermore; these products may also assist in reducing the risks of obesity and heart diseases.

Keywords

Bread, Fibre, Glycerol, Mannitol, Sorbitol, Polyols.

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Introduction

Bakery is the third largest among Food Industries. The increase in the growth rate is due to setting of more automatic plants, increased availability of raw materials of consistent quality, adoption newer bakery products and reduction of product cost. Research work has been carried out on improvement in quality of raw materials, use of additives to improve quality but work on extension of shelf life of bread is lacking.

Polyols are hydrogenated form of carbohydrates, whose carbonyl group had been reduced to primary or secondary hydroxyl groups. They are commonly used in place of table sugar and often in combination with high intensity artificial sweeteners to counter the low sweetness. Polyols also mask the after taste of some high intensity sweeteners. They do not brown or caramelize when heated. These are incompletely absorbed in blood stream hence prevent the risk of diabetes mellitus. These make popular sweeteners among the diabetics and people on low carbohydrate diet. Polyols are also used as humectants and desiccant in food products (Cammanga *et al.,* 1996).

Fiber has many health benefits. Eating soluble fiber had been shown to reduce the risk of developing heart disease by reducing cholesterol levels. Insoluble fibers reduce the risk of constipation, colitis, colon cancer and even haemorrhoids. Diabetics on high-fiber diets need much less insulin. The dietary fibre has a number of nutritional advantages. It has hypocholesteromic/ hypolipidemic effects and consumption of high fibre food items is very useful for the persons suffering from atherosclerosis, constipation, obesity and diabetes etc. Preservation in bakery means the retardation of staling problem in bread. Incorporation of dietary fibre obtained from cereals could be very useful to improve the texture and prolong the shelf life without staling.

Research work has been carried out on improvement in quality of raw materials, use of additives to improve quality but work on extension of shelf life of bread is lacking. However, very little information is available on the incorporation of polyols and fibre in combination in bread making. In developing new food products, it is important to balance the quality and quantity of wheat protein that offer optimum loaf volume to bread, nutritional value and cost effectiveness. Keeping these points in mind, present study was planned with the objectives to optimize and to find out the best level of polyols and fibres on the basis of quality, to find the overall acceptability of the bread on the basis of sensory evaluation by panelists and to study the shelf life of bread prepared after incorporation of polyols and fibres in suitable packaging material.

Materials and Methods

Raw materials

Flour, sugar, polyols (glycerol, sorbitol and mannitol), fibres (oat, psyllium and barley), salt, yeast and other ingredients for product preparation were procured from local market.

Treatments

Breads prepared with incorporation of polyols (glycerol, sorbitol and mannitol) and fibres (oat, psyllium and barley) at levels of 0-6 % were packed in different packaging materials (Low density Polyethylene and Polypropylene) and stored under ambient (30±1ºC) and refrigerated (4-6ºC) conditions.

Chemical analysis

Physico-chemical characteristics of raw materials determined using standard procedures (AACC 2000).

Product preparation

Bread was prepared with slight modification of procedures given in AACC (2000).

Sensory evaluation

Product prepared was evaluated for sensory properties by panel of semi trained judges (Larmond, 1970).

Calorific value

Calorific value was determined by using Bomb Calorimeter, Parr Calorimeter Assembly-6100 (Parr Instrument Company, Moline, Ilinois 61265, U.S.A).

Shelf life

Bread was stored for 10 days at ambient and refrigerated temperatures and analyzed for moisture, water activity and free fatty acid.

Observations

Physico-chemical analysis of both raw materials and product was done according to standard procedures. Organoleptic quality and shelf life studies of finished product were done.

Statistical analysis

Data obtained was subjected to techniques of analysis of variance (ANOVA) (Singh *et al.,* 1991).

Results and Discussion

Pasting properties of flour used for bread making

The effect of incorporation of polyols (glycerol, sorbitol and mannitol) at 2, 4 and 4 % level in combination with fibres (oat, psyllium and barley) at 2 % each in flour on pasting properties of flour for bread making is discussed in Table 1.

The pasting temperature for polyols, fibre and flour blend varied significantly. It increased with the increased level of addition of polyols and fibres as compared to control. Peak viscosity indicated the water binding capacity of starch or mixture. Peak viscosity occurred at the equilibrium point between swelling and polymer leaching. Peak viscosity for blend of oat fibre (2 %) with glycerol (2 %) was 1150 cP, which was less than peak viscosity for oat fibre (2 %) with mannitol (4 %) blend which was 1108 cP. The reduction in peak viscosity indicates a reduced degree of starch granule swelling. Peak viscosity for different levels of polyols and fibre incorporation in flour varied significantly. There was significant variation for final viscosity for blends of polyols with fibres in flour. Final viscosity indicated the ability of the material to form a viscous paste or gel after cooking and cooling. Final viscosity for blend of glycerol (2 %) with oat fibre (2 %) was 1364 cP which was more than the viscosity for mannitol (4 %) and oat fibre (2 %) blends which was 1310 cP. It decreased for psyllium and barley fibres similar to that of oat fibre with polyols. The gel formed at the end of rapid visco analyser (RVA) cooling cycle was essentially a three dimensional network of interwined amylose molecules incorporating dispersed, swollen and ruptured starch granules (Langton and Hermansoon 1989). The decreased final viscosity of sample with added fibre suggested that the three dimensional network was weakened by the presence of fibre in matrix particularly by those of larger particle size water insolubility. Breakdown and setback viscosity for blends of polyols and fibre in flour also varied significantly.

Baking quality of bread

The effect of incorporation of combination of fibres and polyols on baking quality of bread is presented in Table 1. Significant variations were observed in bake absorption, loaf height, loaf weight, loaf volume and specific volume of bread incorporated with combination of polyols and fibres. Bake absorption for control bread was 68 %. Loaf height for control was 9.40cm. Loaf weight for bread prepared from flour supplemented with combination of oat fibre (2 % glycerol, 4 %

sorbitol and 4 % mannitol was 9.40cm, 9.20cm and 9.47cm, respectively. Loaf height of bread with combination of 2 % psyllium fibre, 2 % glycerol, 4 % sorbitol and 4 % mannitol were 8.73cm, 9.37cm and 9.27cm, respectively. Loaf weight of bread which was prepared from polyols and fibre blends varied significantly. Loaf weight of bread prepared from flour supplemented with the combination of 2 % oat fibre with 2 % glycerol, 4 % sorbitol and 4 % mannitol was 156g, 155.62g and 151.83g, respectively as compared to control which was 146.05g. Loaf weight of bread prepared from flour supplemented with the combination of 2 % psyllium fibre and 2 % glycerol, 4 % sorbitol and 4 % mannitol was 159.61g, 152.36g and 143.50g, respectively. Loaf weight of bread prepared from flour with the combination of 2 % barley fibre along with 2 % glycerol, 4 % sorbitol and 4 % mannitol was 155.67g, 159.64g and 154.78g, respectively. For all the combination loaf weight increased when fibre and polyols were used in combination, more with barley in combination with polyols due to increased water absorption capacity.

Loaf volume of bread prepared from combination of polyols and fibres also varied significantly. Loaf volume of bread prepared from flour supplemented with combination of 2 % oat fibre along with 2 % glycerol, 4 % sorbitol and 4 % mannitol were 648.66cc, 646.33cc and 637.67cc, respectively in the order as compared to control which was 697.33cc. Loaf volume of bread prepared from flour supplemented with combination of 2 % psyllium fibre along with 2 % glycerol, 4 % sorbitol and 4 % mannitol were 619.00cc, 672.33cc and 627.33cc, respectively. Bread prepared from flour supplemented with combination of 2 % barley fibre along with 2 % glycerol, 4 % sorbitol and 4 % mannitol were 632.33cc, 643.00cc and 632.66cc, respectively. Loaf volume was decreased by increasing level of these combinations. This might have been due to decreased gas holding capacities with the incorporation of polyols and fibres.

Specific volume for bread prepared from combination of polyols and fibre varied significantly. Specific volume for control bread was 4.77cc/g. Specific volume of bread prepared from flour supplemented with combination of 2 % oat fibre along with 2 % glycerol, 4 % sorbitol and 4 % mannitol were 4.16cc/g, 4.15cc/g and 4.19cc/g, respectively which were slightly less than control (4.77cc/g). Specific volume of bread prepared from flour supplemented with combination of 2 % psyllium fibre along with 2 % glycerol, 4 % sorbitol and 4 % mannitol were 3.87cc/g, 4.41cc/g and 4.37cc/g, respectively. Specific volume of bread prepared from flour supplemented with combination of 2 % barley fibre along with 2 % glycerol, 4 % sorbitol and 4 % mannitol were 4.06cc/g, 4.03cc/g and 4.09cc/g, respectively. All the breads were having very good specific volume. From the selected three best combinations of polyols and fibre i.e. 2 % oat fibre and 2 % glycerol, 2 % psyllium fibre and 4 % sorbitol, 2 % barley fibre and 4 % sorbitol were selected best for further storage studies. Flour supplemented with 2 % level of psyllium fibre and 2 % level of glycerol had higher bake absorption. Dough made with 5 % psyllium husk had undesirable stickiness that especially complicated dough mixing (Park *et al.*, 1997) resulted in decreased volume. Chen *et al.*, (1988) suggested a possible interaction between fiber and gluten that prevent their complete hydration and resulted in poor gluten development during mixing and hence reduced volume.

Sensory evaluation of bread

The effect of incorporation of combination of fibres and polyols on the mean sensory panel scores of bread is discussed in Table 1.

Significant variations were observed with regard to organoleptic score for color and flavor while non-significant for appearance, texture and overall acceptability for the breads prepared from flour supplemented with combination of fibres and polyols and evaluated by semi trained panel of judges on 9-point hedonic scale (Fig. 1).

Score for the color of bread prepared after incorporation of combination of 2 % psyllium fibre along with 2 % glycerol, 4 % sorbitol and 4 % mannitol were 7.40, 7.90 and 8.10, respectively. Psyllium fibre was found to have negative effect on the color of bread.

This could have been because of appearance of black specks on dark brown background and these were increased with increase in levels of incorporation of psyllium fibre. Similar results were obtained by Park *et al.*, (1997).

Maximum score for the overall acceptability of bread was observed for the combination of 2 % oat fibre and 2 % glycerol, 2 % psyllium fibre and 4 % sorbitol, and 2 % barley fibre and 4 % mannitol and were 8.35, 8.50 and 8.30, respectively. These combinations were selected for further storage studies.

Textural properties of bread

Significant variations were observed for hardness and resilence of bread prepared with polyols and fibres (Table 1). Hardness for control sample was 5.89 N. Hardness for the bread prepared from flour supplemented with combination of 2 % oat fibre along with 2 % glycerol, 4 % sorbitol and 4 % mannitol was 3.61 N, 4.27 N and 5.01 N, respectively.

Minimum hardness was 3.61 N for 2 % oat fibre and 2 % glycerol supplemented bread. This yielded the more softened bread. Hardness for the bread prepared from flour supplemented with combination of 2 % psyllium fibre along with 2 % glycerol, 4 % sorbitol and 4 % mannitol were 3.52 N, 3.46 N and 3.78 N, respectively. Minimum hardness was observed for 2 % psyllium fibre and 4 % sorbitol supplemented bread. Hardness for the breads which were prepared from flour supplemented with combination of 2 % barley fibre along with 2 % glycerol, 4 % sorbitol and 4 % mannitol were 4.49 N, 3.39 N and 3.52 N, respectively. Minimum hardness for bread was observed for 2 % barley fibre and 4 % sorbitol supplemented bread and regarded as best combination.

Resilence for the bread prepared from combination of polyols and fibre varied significantly. Resilence for bread prepared from flour supplemented with 2 % barley fibre along with 2 % glycerol. 4 % sorbitol and 4 % mannitol was 0.31, 0.47 and 0.39, respectively.

So the larger loaf had less dense gluten network giving less resistance to compression (Lombard *et al.,* 2000). Working with cakes Cauvain and Cyster (1996) found that added glycerol resulted in a softer crumb structure. As compared with control the combination of fibre and polyols when incorporated in the formula for bread making improved the textural properties and produced softer bread. This might have been due to increased water holding capacities because of the addition of fibres and humectant property of polyols.

Calorific value of bread

The data revealed some decrease in the calorific value after incorporation of polyols and fibre in the formula. Calorie reduction (%) for bread prepared with 2 % oat fibre and 2 % glycerol, 2 % psyllium fibre and 4 % sorbitol; and 2 % barley fibre and 4 % sorbitol were 6.55 %, 12.42 % and 5.86 %, respectively.

Table.1 Effect of incorporation of combination of fibres and polyols on pasting properties, baking quality, overall acceptability and textural property of bread

Fibres	Level (%)	Polyols	Level (%)	Paste temperature (^{0} C)	Setback viscosity (cP)	Bake absorption (%)	Loaf height (cm)	Loaf weight (g)	Loaf volume (cc)	Specific volume (cc/g)	Overall acceptability	Hardness (N)	Resilence
Control	0	-	0	93.10	762.00	68.0	9.40	146.05	697.33	4.77	8.27	5.89	0.32
Oat	2	Glycerol	2	89.50	761.00	76.2	9.40	156.00	648.66	4.16	8.35	3.61	0.38
	2	Sorbitol	4	92.00	715.00	75.0	9.20	155.62	646.33	4.15	8.20	4.27	0.37
	2	Mannitol	4	93.10	713.00	75.3	9.47	151.83	637.67	4.19	8.30	5.01	0.41
Psyllium	2	Glycerol	2	84.00	741.00	75.3	8.73	159.61	619.00	3.87	8.02	3.52	0.41
	2	Sorbitol	4	90.00	711.00	76.6	9.37	152.36	672.33	4.41	8.50	3.46	0.33
	2	Mannitol	4	90.10	318.00	76.1	9.27	143.50	627.33	4.37	8.32	3.78	0.37
Barley	2	Glycerol	2	93.50	748.00	76.0	9.20	155.67	632.33	4.06	8.10	4.49	0.31
	2	Sorbitol	4	93.60	711.00	77.1	9.30	159.64	643.00	4.03	8.30	3.39	0.47
	2	Mannitol	4	94.40	768.00	78.2	9.13	154.78	632.66	4.09	8.27	3.52	0.39
	***LSD (p<0.05)**			0.17	0.38	0.19	0.37	1.48	32.46	0.20	*NS	0.12	0.17

*LSD- Least significant difference
*NS- Non significant

Table.2 Effect of packaging material, storage conditions and storage period on moisture content (%) of bread

Days	Storage condition															
	Ambient (30±1^0 C) Packaging material								Refrigeration (4-6^0 C) Packaging material							
	LDPE				PP				LDPE				PP			
	F_1	F_2	F_3	F_4	F_1	F_2	F_3	F_4	F_1	F_2	F_3	F_4	F_1	F_2	F_3	F_4
0	35.67	40.91	41.88	40.73	35.45	41.25	41.36	41.85	36.46	41.25	43.15	41.98	36.80	41.02	42.69	40.56
2	34.79	36.27	41.63	39.35	35.15	34.95	40.55	40.95	36.49	41.65	43.35	42.08	37.00	41.30	43.09	41.25
4	35.53	35.78	38.39	37.14	34.85	34.65	34.25	40.05	36.52	42.05	43.57	42.20	37.20	41.62	43.43	41.91
6	33.25	35.13	34.72	35.55	34.55	34.35	33.95	39.15	36.55	42.45	43.79	42.35	37.40	41.94	43.79	42.56
8	31.58	34.80	34.47	34.66	34.25	34.05	33.65	38.25	36.58	42.85	43.92	42.41	37.70	42.22	44.21	43.13
10	31.07	33.67	33.25	33.28	33.95	33.75	33.35	37.35	36.61	43.25	44.23	42.56	37.90	42.54	44.79	44.26
LSD (p<0.05)	2.82				0.16				0.16				0.13			

LSD- Least significant difference, LDPE – Low density polyethylene, PP – Polypropylene
F_1 – Control, F_2 - 2% Oat fibre + 2% Glycerol
F_3 - 2% Barley fibre + 4% Sorbitol, F_4 - 2% Psyllium fibre + 4% Sorbitol

Table.3 Effect of packaging material, storage conditions and storage period on water activity of bread

Days	Storage condition															
	Ambient (30±1⁰ C) Packaging material								Refrigeration (4-6⁰ C) Packaging material							
	LDPE				PP				LDPE				PP			
	F_1	F_2	F_3	F_4	F_1	F_2	F_3	F_4	F_1	F_2	F_3	F_4	F_1	F_2	F_3	F_4
0	0.83	0.80	0.81	0.80	0.83	0.80	0.81	0.80	0.83	0.80	0.81	0.80	0.83	0.80	0.81	0.80
2	0.83	0.82	0.82	0.81	0.83	0.82	0.83	0.81	0.83	0.82	0.81	0.81	0.83	0.81	0.82	0.82
4	0.84	0.83	0.84	0.83	0.84	0.83	0.83	0.84	0.86	0.84	0.82	0.83	0.84	0.83	0.84	0.83
6	0.86	0.84	0.84	0.85	0.85	0.85	0.84	0.86	0.87	0.86	0.84	0.85	0.85	0.86	0.84	0.85
8	0.88	0.85	0.85	0.86	0.86	0.86	0.85	0.87	0.89	0.88	0.88	0.85	0.88	0.87	0.85	0.87
10	0.90	0.86	0.87	0.88	0.91	0.87	0.88	0.89	0.92	0.89	0.90	0.87	0.93	0.89	0.88	0.90
LSD ($p<0.05$)	0.014				0.021				0.011				0.019			

LSD- Least significant difference, LDPE – Low density polyethylene, PP – Polypropylene

F_1 - Control

F_2 - 2% Oat fibre + 2% Glycerol

F_3 - 2% Barley fibre + 4% Sorbitol

F_4 - 2% Psyllium fibre + 4% Sorbitol

Table.4 Effect of packaging material, storage conditions and storage period on free fatty acid content (% oleic acid) of bread

Days	Storage condition															
	Ambient (30±1⁰ C) Packaging material								Refrigeration (4-6⁰ C) Packaging material							
	LDPE				PP				LDPE				PP			
	F_1	F_2	F_3	F_4	F_1	F_2	F_3	F_4	F_1	F_2	F_3	F_4	F_1	F_2	F_3	F_4
0	0.070	0.065	0.075	0.052	0.063	0.061	0.072	0.054	0.055	0.053	0.060	0.050	0.052	0.053	0.059	0.051
2	0.080	0.070	0.078	0.069	0.069	0.068	0.074	0.059	0.058	0.055	0.068	0.052	0.059	0.056	0.063	0.056
4	0.080	0.069	0.083	0.072	0.073	0.070	0.079	0.063	0.064	0.059	0.069	0.055	0.062	0.059	0.065	0.060
6	0.075	0.072	0.080	0.075	0.076	0.073	0.081	0.071	0.066	0.062	0.072	0.059	0.064	0.062	0.070	0.062
8	0.061	0.078	0.081	0.080	0.081	0.075	0.084	0.075	0.070	0.067	0.077	0.063	0.068	0.065	0.071	0.070
10	0.095	0.081	0.089	0.085	0.090	0.079	0.087	0.077	0.072	0.072	0.079	0.072	0.070	0.069	0.074	0.072
LSD ($p<0.05$)	0.016				0.016				0.009				0.011			

LSD- Least significant difference, LDPE – Low density polyethylene, PP – Polypropylene

F_1 - Control

F_2 - 2% Oat fibre + 2% Glycerol

F_3 - 2% Barley fibre + 4% Sorbitol

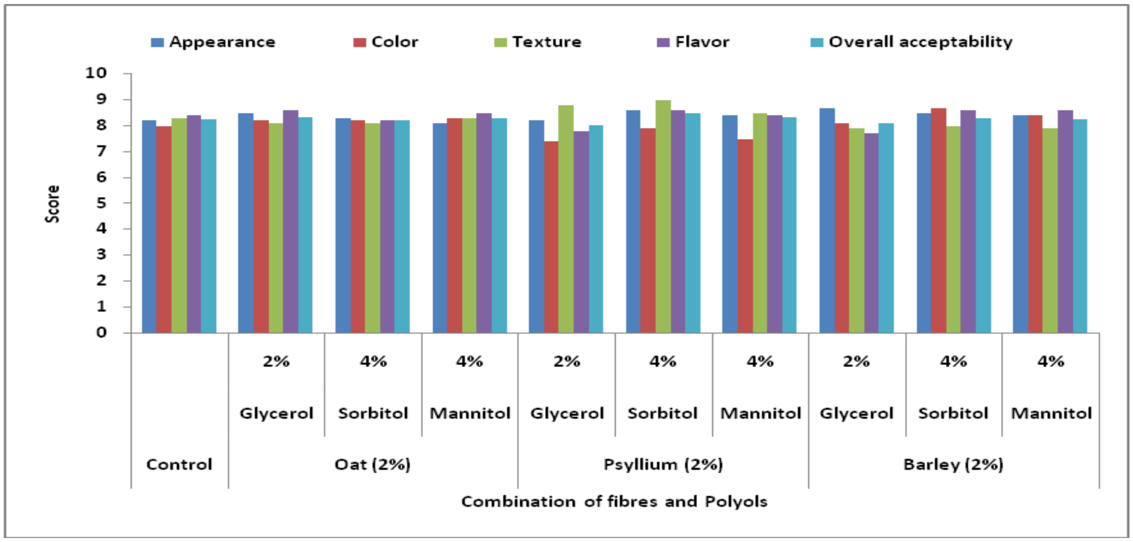
F_4 - 2% Psyllium fibre + 4% Sorbitol

Table.5 Effect of packaging material, storage conditions and storage period on yeast and mold count (cfu per g) of bread

Days	Storage condition															
	Ambient (30±1^0 C)								Refrigeration (4-6^0 C)							
	Packaging material								Packaging material							
	LDPE				PP				LDPE				PP			
	F_1	F_2	F_3	F_4	F_1	F_2	F_3	F_4	F_1	F_2	F_3	F_4	F_1	F_2	F_3	F_4
0	1.88x10^2	1.61x10^2	1.72x10^2	1.61x10^2	1.79x10^2	1.72x10^2	1.36x10^2	1.62x10^2	1.79x10^2	1.57x10^2	1.63x10^2	1.64x10^2	1.72x10^2	1.66x10^2	1.61x10^2	1.54x10^2
2	1.93 x10^2	1.83x10^2	1.74x10^2	1.72x10^2	1.83x10^2	1.76x10^2	1.69x10^2	1.65x10^2	1.88x10^2	1.68x10^2	1.70x10^2	1.67x10^2	1.78x10^2	1.71x10^2	1.63x10^2	1.62x10^2
4	1.99 x10^2	1.91x10^2	1.82x10^2	1.84x10^2	1.92x10^2	1.99x10^2	1.77x10^2	1.78x10^2	1.97x10^2	1.79x10^2	1.76x10^2	1.75x10^2	1.88x10^2	1.82x10^2	1.68x10^2	1.74x10^2
6	2.33 x10^2	2.10x10^2	1.91x10^2	1.90x10^2	2.1 x10^2	2.51x102	1.85x10^2	1.81x10^2	2.21x10^2	1.93x10^2	1.83x10^2	1.84x10^2	2.05x10^2	1.98x10^2	1.73x10^2	1.78x10^2
8	2.78 x10^2	2.16x10^2	2.13x10^2	1.98x10^2	2.36x10^2	2.78x10^2	2.20x10^2	1.92x10^2	2.74x10^2	2.1 x10^2	2.05x10^2	1.92x10^2	2.31x10^2	2.16x10^2	1.9 x10^2	1.89x10^2
10	3.18 x10^2	2.83x10^2	2.75x10^2	1.74x10^2	2.94x10^2	2.92x10^2	2.59x10^2	2.64x10^2	2.89x10^2	2.3 x10^2	2.40x10^2	2.53x10^2	2.80x10^2	2.54x10^2	2.29x10^2	2.18x10^2
LSD ($p<0.05$)	7.07				7.60				7.15				5.66			

cfu- colony forming unit
LSD- Least significant difference
LDPE – Low density polyethylene
PP – Polypropylene
F_1 - Control
F_2 - 2% Oat fibre + 2% Glycerol
F_3 - 2% Barley fibre + 4% Sorbitol
F_4 - 2% Psyllium fibre + 4% Sorbitol

Fig.1 Effect of incorporation of combination of fibres and polyols on the mean sensory panel score (max 9) of bread



Shelf life of bread

Shelf life of breads with best level of polyols and fibres was further studied. Breads were analysed for moisture, water activity, free fatty acid and microbial load under ambient (30±1ºC) and refrigerated ($4\text{-}6^0$ C) temperature conditions.

Moisture content of bread

Statistically significant variations were observed in the moisture content of bread to the days of storage, packaging material and temperature (Table 2). The bread stored under ambient conditions showed a higher rate of moisture loss than those stored under refrigerated conditions.

Higher moisture content was observed in bread prepared with incorporation of 2 % psyllium fibre and 4 % level of sorbitol as compared to control. Psyllium fibre had high capacity to absorb water than other fibre sources and sorbitol had more humectancy than other polyols (glycerol and mannitol). So the bread prepared after incorporation of 2 % psyllium fibre and 4 % sorbitol had maximum moisture content. Bread stored at ambient conditions showed a higher rate of moisture loss than those stored under refrigerated conditions. Bread packed in LDPE showed a higher rate of moisture loss than those packed in PP packaging material.

Rossel *et al.*, (2001) also reported that oat flour had higher water absorption and water retention values, so the bread had higher moisture level which delayed staling. Moisture retention property of oat keeps bread fresher for longer period of time. Hardness of breads increased over time. The initial rate of firming was rapid, showing down over time. The lower compression force value for the yeast leavened bread could be due to yeast leavening resulting in a lighter, more open crumb structure with larger holes (Lombard *et al.*, 2000). Higher moisture retention in bread is economical and also required to lengthen shelf life. Bread moisture content-after baking indicates the quality and can be directly correlated to shelf life of produce. Changes in bread moisture were noted after baking at 0, 2, 4, 6, 8 and 10 days (Asghar *et al.*, 2006).

Water activity of bread

Statistically significant variations were observed in the water activity of bread prepared with polyols and fibres with respect to day of storage, packaging material and temperature of storage (Table 3). While the interaction between type of bread and packaging material was not significant. Bread stored under ambient conditions showed a lower water activity than these stored under refrigerated conditions. Bread packed in LDPE showed a lower water activity than those packed in PP packaging material. At refrigeration storage, water activity increased with the storage time (Frazier 1978). Arya (1980) reported that storage at less than 0.57 a_w did not cause perceptible change in flavor for 24-52 days. Glycerol was reported to increase the shelf life stability of wheat and corn tortillas. Petrizzelli (1988) developed shelf life of intermediate moisture dough or pastry made from 30-40 % native starch, 15-25 % fat, 5-10 % water and 2-5 % glycerol or 4-7 % sorbitol with emulsifier, salt and flavoring. The water activity of product was 0.6- 0.8. Rossel *et al.,* (2001) reported that the hydroxyl group of the fibre structure which allow more water interaction through hydrogen bonding. Oat starch had higher water absorption than other cereals. Bread water activity was varied by glycerol level. Sugar alcohols were the low molecular weight. This has influence in lowering the water activity of food and its high osmotic pressure lead to an increased preservative effect and extended shelf life. Low molecular weight may help in lowering the freezing point depression in frozen products.

Free fatty acid content (% oleic acid) of bread

Statistically significant variations were observed in development of free fatty acids in the breads stored under ambient conditions but in different packaging material (Table 4). The development of free fatty acids was lower in case of bread and it was found to be highest on the 10th day of storage. Bread stored at ambient condition showed higher amount of free fatty acid than bread stored at refrigeration conditions. Bread packed in LDPE had higher values of free fatty acids than bread packed in PP. This could have been because of the fact that PP had less WVTR as compared to LDPE. This was because of gain of moisture by the product which promoted oxidation of fats. Similar results were obtained by Singh *et al.,* (2000) who reported that free fatty acid content of all biscuits increased gradually with the increase in the storage period. They also reported that the acid value in different categories of biscuits increased after 60 days of storage at room temperature.

Yeast and mold count (cfu per g) of bread

Statistically significant variations were observed in the yeast and microbial count of breads packed in LDPE and PP packaging materials during storage studies (Table 5). It was observed that the average growth of bacteria, yeast and mold was comparatively less in polyols and fibre incorporated bread than the control bread. It was also observed that bread packed in LDPE exhibited higher microbial growth than those packed in PP. Spoilage of breads due to mold growth was observed during study. Under refrigerated condition no spoilage was observed up to 10th day of storage. No growth was found to occur in fibre, polyols breads even up to 10th day of storage under ambient conditions. This could have been due to antimicrobial properties of fibre and low water activity of breads with polyols. Baking process ordinary destroy all bacterial cells, yeast and mold spores (Frazier 1978). Islam (1982) reported that loaves made without any preservative spoiled by the fifth day of storage. The shelf life of bread could be enhanced after incorporation of fibres and polyols.

Esteller *et al.,* (2004) examined the impact of replacing the sugar in bread formulations with various sweeteners (fructose syrup, crystalline fructose, anhydrous glucose, honey, invert sugar) on quality and shelf life of bread. Various bread formulations were prepared using the sweeteners, maintaining the sweetness and contents of TS and water as in the original formulation. The dough was baked at 225°C for 8 min. Results showed that different kinds of sugars alone or in combination could be used in bread making to improve products softness and shelf life.

The main reason for low TPC and yeast and mold count of bread formulated with polyols and fibres was due to the fact that this bread had lower water activity as compared to control bread because of addition of hygroscopic polyols and fibres. Md Ayub *et al.,* (2003) observed the minimum microbial growth as (0-57cfu/g) for S_1 (from registered baking industries) and maximum for S_4 (collected from local market of Peshawar) (0-97cfu/g). Selected sample of breads were analyzed for total microbial count by the total plate count method (Diliello, 1982). The results were in agreement with the finding of Collins *et al.,* (1991) who isolated 202 bacillus strains from ropy bread and characterized according to colony morphology.

Gliemmo *et al.,* (2004) showed the effect of glucose or polyols on sorbate stability and on its antimicrobial action were studied in aqueous system (pH 3). Xylitol increased the lag phase and stationary phase of *Zagosaccharomyces bacilli*. So addition of polyols and fibres might have been increased the lag phase of spoilage microorganism.

Significant variations in different parameters were observed. Moisture content and water activity were higher for bread prepared from combination of 2 % oat fibre along with 2 % glycerol, 2 % barley fibre along with 9 % sorbitol and 2 % psyllium fibre along with 9 % sorbitol as compared to control bread and it was observed that moisture content was higher in products packed in PP. Water activity was higher for products packed in PP. At refrigeration storage, water activity increased with the increased storage time. Free fatty acid content (% oleic acid) was observed to be higher in the bread stored at ambient condition and which were packed in LDPE packaging material. Bread incorporated with polyols and fibres were acceptable after storage period of 10 days in PP under ambient conditions. Apart from increase in shelf life, fibres and polyols could be helpful in producing specialty foods for consumption of people suffering from diabetics furthermore; these products may also assist in reducing the risks of obesity and heart diseases.

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