Development and evaluation of garlic incorporated ready-to-eat extruded snacks

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Abstract The present study was carried out to develop and evaluate ready to eat extruded snacks incorporated with garlic powder at various levels (5 %, 10 %, 15 %, 20 %). The organoleptic evaluation was conducted for the developed products and the well accepted products were selected for further studies like physical properties and shelf life (stored at room temperature for 2 months). The organoleptic evaluation of the developed snacks revealed that 15 % and 20 % garlic incorporated snacks were not acceptable due to strong garlic flavor, therefore T₁ (control), T₂ (5 % garlic) and T₃ (10 % garlic) were selected for further studies. The physical properties showed significant changes with incorporation of garlic powder at 0 %–10 % level. There was an increase in mass flow rate, tap density and bulk density but decrease in the water holding capacity, oil absorption capacity and expansion ratio. The water soluble index and moisture retention of the products showed the same values for all the three selected treatments. The products were packed by ordinary, nitrogen and vacuum packing and stored for 2 months. It was found that there was an increase in moisture content and microbial load, however the increase was within limits. The increase in the moisture content was low in nitrogen packed products where as the microbial load decreased with increase in the percentage of garlic incorporation. The nitrogen and vacuum packed products showed less microbial load than the ordinary packed products. Garlic powder can be incorporated at 5 and 10 % levels in

ready-to-eat extruded snacks with well acceptability and can be stored for a period of 2 months with nitrogen packing as an effective packaging.

Keywords Garlic powder · Extruded snacks · Mass flow rate · Tap density · Bulk density · Water soluble index · Moisture retention · Microbial load

Introduction

Snacks have become a rapid food solution. A key marketing opportunity exists for the development of functional snacks that will meet both the increasing demand for snacks and their need to be “healthy” (Euromonitor 2002). Snacks have become one of the major groups of the functional food products (Roberts 2002) since more women are working, changing, and extended working hours, increasing number of single person households, different eating times, and food choices by individual family members, kids’ buying power, consumer’s need for indulgence, and increasing perception of food as a reward (Promar International 1997; Euromonitor 2002). In the modern cereal based industry, extrusion technology plays a central role especially for the production of snack foods from corn, wheat and rice. However, rice has relatively low protein content (6–8 g/100 g db) and an amino acid profile that is high in glutamic and aspartic acid while lysine is the limiting amino acid (majumdar et al. 2011). Thus proteinaceous additives like soy flour and herbs like garlic are needed to ensure nutritional diets.

Good snacks should be convenient to consume, inexpensive, nutritious, low in fat, and have a long shelf life. Wangcharoen et al. (2002a, b) and garlic was the most preferred herb in snacks (Ngarmsak et al. 2002). Garlic is commonly used as a medicinal agent for thousands of years which has multiple beneficial effects such as anti-microbial, anti-thrombotic, antimicrobial, hypolipidemic, anti-arthritis,

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hypoglycemic and anti-tumor activity (Martha and Muslim 2003). Randomized controlled trials have supported the lipid lowering effect of allicin in garlic and other breakdown products which could significantly reduce cholesterol as compared with placebo (Benjamin et al. 1983; Warshafsky et al. 1993; Silagy and Neil 1994; Koch and Lawson 1996; Stevinson et al. 2000; Ackermann et al. 2001).

The difficulty in formulating any spice blend is in deciding how much of each spice to add to achieve a desired flavour and beneficially improve consumer health. The recommended daily doses are 600–900 mg (Brown 1996; Blumenthal et al. 1998) and 400–1,200 mg (Fisher and Painter 1996) for garlic powder. Therefore, the objective of this study was to establish the optimum levels of garlic powder in rice + defatted soy powder extruded snacks, where optimum level was defined as being the level that met the dual needs of being well-liked and imparting health benefits to the consumer.

Materials and methods

Rice flour (*Oryza sativa* L), defatted soy flour (*Glycine max*), garlic bulbs (*Allium sativum*), and salt were procured from a supermarket in Hyderabad, India. Garlic bulbs were manually separated into cloves, peeled and dried in a hot air cabinet dryer at 60° C for 6 h (Ratti et al. 2007). The dried cloves were then ground into fine powder and stored in an air tight container for further use.

Preparation of the feed for extrusion was made by incorporating garlic powder at 5 % (T₂), 10 % (T₃), 15 % (T₄), 20 % (T₅) levels with rice flour and defatted soy flour. T₁ (control) was blended with rice flour and defatted soy flour and the feed for extrusion was (T₁) consequently made by reducing percentage of rice flour in accordance with the garlic powder incorporation. The overall defatted soy flour was adjusted to 30 % in all the samples and the highest and lowest rice flour were 67.5 % and 47.5 %. The formulated mixes were mixed thoroughly and their moisture content was estimated and adjusted to 17 % in all the formulations to condition the mix. This mix was thoroughly sieved to avoid any lumps and left for conditioning for 1 h. The conditioned flour was extruded with a co-rotating twin screw extruder by HTST (High Temperature Short Time) method.

The acceptability of the five developed products was evaluated by sensory evaluation method. Score card of 100 point composite scoring method (Joshi 2006) was developed to analyse the acceptability of the products based on the various sensory attributes like flavour, texture, colour, odour, expansion and the overall acceptability for evaluation by 15 well trained panel members at PGRC (Post Graduate and Research Centre), Rajendranagar. The well accepted products were studied for physical properties like mass flow rate, density of extrudate, bulk density, water soluble index,

water holding capacity, oil absorption capacity, specific mechanical energy, moisture retention, expansion ratio by using standardized methods. The well accepted products were packed by vacuum packing, nitrogen flushing and ordinary packing and shelf life of these products were studied for a period of 2 months. The packed treatments were denoted by letter 'P'. The moisture content and microbial load of the products were tested at 0, 30th and 60th day.

The statistical analysis of sensory evaluation was done by ANOVA (one way) method and for the shelf life studies ANOVA (two factorial CRD) was done. For the physical properties, mean and standard deviations were taken and analysed. The number of replicates done were 3.

Results and discussion

Effect of substitution of rice flour with garlic powder on sensory analysis

The data presented in Table 1 indicate significant differences in scores for flavor, colour, expansion, texture, odour and overall acceptability among the different treatments at ($p < 0.01$) level. The control sample had highest scores for color (13.200), expansion (13.400), texture (13.200) and odour (8.200) which could be due to high percent of rice flour and absence of garlic powder which was in accordance to Bhattacharyya et al. (1997) in rice and green gram extruded products. Analysis of flavor and overall acceptability indicated that the treatment with 5 % garlic powder had highest scores which could be due to low pungency and higher expansion. Similar results were found by Gamlath and Ravindran (2009) in the development of chickpea–rice blend extruded snacks up to 15 % incorporation of fenugreek in the form of debittered polysaccharide. Therefore, the control sample (T₁), 5 % garlic incorporated sample (T₂) and 10 % garlic incorporated sample (T₃) were selected for further studies.

Effect of substitution of rice flour with garlic powder on physical properties of the product

Product characteristics of extrudates made from rice and other starchy ingredients depend on physicochemical changes that occur during extrusion due to the effects of extrusion variables (Pansawat et al. 2008).

Mass flow rate Mass flow rate is the weight of product extruded for a specific period of time and it was determined by taking the weight of the product extruded per second (Zasytkin and Tung-Ching 1998). From Table 2, it was evident that substitution of rice flour with garlic powder increased the mass flow rate of the product with increase in garlic percentage. The mass flow rate of the products

Table 1 Effect of substitution of rice flour with garlic powder on sensory analysis

Sensory parameter	Treatment (means)					F ratio		S.E	C.D
	T ₁	T ₂	T ₃	T ₄	T ₅	R	T	T	T
Flavour	23.53	23.80	21.80	18.26	15.26	5.43**	13.15**	1.0145	2.874
Colour	13.20	12.73	11.00	10.46	9.86	8.08**	24.52**	0.2923	0.828
Expansion	13.40	12.60	10.20	10.13	8.26	2.46**	33.36**	0.3584	1.015
Texture	13.20	12.46	11.80	9.667	9.133	2.30*	18.78**	0.4091	1.159
Odour	8.200	8.000	7.400	7.067	5.867	2.70**	8.32**	0.3205	0.908
Overall acceptability	12.66	13.00	11.60	8.93	8.26	2.75**	24.27**	0.4403	1.247

R- replicates, $n=3$ T- Incorporation of garlic- T₁ (0, Control), T₂ (5 %), T₃ (10 %), T₄ (15 %) and T₅ (20 %)*significant at $p<0.05$ **significant at $p<0.01$

were 2.69, 2.95 and 3.05 for the garlic incorporation at zero, 5 and 10 % levels. This could be due to low percent of rice flour and less expansion and hygroscopic nature of garlic.

Density of the extrudate The products with highest expansion index and low product density which generally are good characteristics of extruded snacks were produced at highest temperature and moderate to high screw speed with lowest die diameter (Majumdar et al. 2011). Table 2 indicates the difference in the tap density and bulk density of the three treatments and they increased with increase in the percentage of garlic incorporation. The increase in tap density was 0.51 g/cc, 0.80 g/cc, 0.82 g/cc respectively when garlic incorporation was 0, 5 and 10 % which possibly could be due to the decreased expansion ratio with increased garlic incorporation and therefore more quantity of product could be accommodated. The bulk density too increased because of decreased expansion ratio with increased garlic incorporation which are in accordance to El-Samahy et al. 2007 and Bhattacharyya et al. 1997. Guha et al. (1997) reported that the combination of high temperature and high screw speed yielded a product with low density.

Water soluble index (WSI) The WSI was measured using a technique developed for cereals (Anderson et al. 1969). Table 2 indicated that there is no significant difference in the WSI of the three treatments (10 %) and the products did not show any difference with the increase in the garlic incorporation. The water solubility index (WSI) describes the rate and extent to which the component of powder material or particles dissolves in water. It depends mainly on the chemical composition of the powder and its physical state. The WSI often is used as an indicator of degradation of molecular components (Kirby et al. 1988), measures the degree of starch conversion during extrusion which is the amount of soluble polysaccharide released from the starch component after extrusion. Binoy et al. (1996) reported that water solubility index increased with severity of screw configuration and Narbutaite et al. (2008) examined that WSI of all extrudates decreased with increasing moisture levels.

Water holding capacity (WHC) It is the amount of water bound to matrices in a particular food system (Neumann et al. 1984). The WHC of the treatments decreased with

Table 2 Effect of substitution of rice flour with garlic powder on physical properties of the product

Physical parameter	Treatments (Mean $\pm$ S.D)		
	T ₁	T ₂	T ₃
Mass flow rate (g/sec)	2.69 $\pm$ 0.12	2.95 $\pm$ 0.045	3.05 $\pm$ 0.068
Density of the extrudate (Tap density g/cc)	0.51 $\pm$ 0.011	0.80 $\pm$ 0.005	0.82 $\pm$ 0.007
Density of the extrudate (Bulk density g/ml)	0.105 $\pm$ 0.006	0.149 $\pm$ 0.001	0.196 $\pm$ 0.015
Water soluble index (%)	10 $\pm$ 0	10 $\pm$ 0	10 $\pm$ 0
Water holding capacity (%)	78.3 $\pm$ 1.46	77.5 $\pm$ 1.26	75.4 $\pm$ 1.66**
Oil absorption capacity (g)	1.42 $\pm$ 0.025	1.39 $\pm$ 0.02	0.93 $\pm$ 0.015
Specific Mechanical energy (Wh/kg)	236.6 $\pm$ 11.06	216 $\pm$ 3	209.3 $\pm$ 4.72**
Moisture retention (%)	11.7	11.7	11.7
Expansion ratio(D/Do)	3.38 $\pm$ 0.10	3.16 $\pm$ 0.32	3.07 $\pm$ 0.43

Refer to Table 1 for T₁-T₃" $n=3$ ** significant at $p<0.01$

increase in the garlic percentage. The decrease in the water holding capacity was 78.3, 77.5 and 75.4 % respectively with increase in the garlic incorporation from zero, 5 and 10 % which may be due to decrease in proportion of rice flour. This condition lowered the amount of starch and hence the water holding capacity. Similar results were observed by Gamlath and Ravindran (2009).

Oil absorption capacity It denotes how much oil is bound to matrices in a particular food system which could be used as the index of hydro phobicity of the food (Kanterewicz et al. 1989). Due to the decrease of rice flour % and presence of 30 % defatted soy flour the oil absorption capacity of the extruded products decreased with increase in garlic incorporation 5 % (1.39 ± 0.02) and 10 % (0.93 ± 0.015) as seen in Table 2 and also higher absorption of oil may be attributed to presence of less fat and more crude fiber in case of extrudate sample prepared which was in accordance to Deshpande and Poshadri 2011

Specific mechanical energy (SME) The mechanical energy input per unit mass of the extrudate, was calculated by dividing the net power input to the screw by the extrudate flow rate (Rosentrater et al. 2005). The SME ranged between 209.3 ± 4.72 to 236.6 ± 11.06 as seen in Table 2, and it was inversely proportional to mass flow rate where Onwulata et al. 2001 had mentioned that Specific mechanical energy integrates extrusion responses, such as net torque, screw speed and the product mass flow rates. Various studies proved that SME also decreased at high moisture content, (Mjoun, and Rosentrater 2011), however moisture being constant in the feed formulation only mass flow rate could impact the SME which was seen to decrease with increase in the mass flow rate.

Moisture retention Moisture retention of the products can be calculated using the product moisture and the moisture of raw material (AOAC 2005). The moisture retention of the products was 11.7 % for all the three treatments. This may

Table 3 Effect of storage on moisture content of the products

Treatments		Days of storage			Mean±S.D
		0	30	60	
Ordinary packed products (%)	P ₁	2.000	4.333	6.333	4.22±2.0
	P ₂	2.000	4.000	5.667	3.88±1.61
	P ₃	2.000	4.667	5.333	4.00±1.73
	Mean±S.D	2.00±0.0	4.33±0.70	5.77±1.09	4.03±1.90
	F Ratio		S.E		C.D
	A	51.94**	0.26450		0.78586
	B	0.41	0.26450		0.78586
	A*B interaction	0.68	0.45812		1.36115
Nitrogen packed products (%)	P ₁	2.333	4.333	4.667	3.77±1.56
	P ₂	2.000	3.667	4.000	3.22±1.20
	P ₃	2.000	4.333	5.333	3.88±1.76
	Mean±S.D	2.11±0.33	4.11±1.26	4.66±1.22	3.62±1.34
	F Ratio		S.E		C.D
	A	13.30**	0.36851		1.09491
	B	0.94	0.36851		1.09491
	A*B interaction	0.30	0.63828		1.89644
Vacuum packed products (%)	P ₁	2.000	4.333	4.667	3.66±1.323
	P ₂	2.333	5.000	4.667	4.00±1.500
	P ₃	2.000	5.000	5.000	4.00±1.658
	Mean±S.D	2.11±0.333	4.77±0.833	4.77±0.833	3.88±1.53
	F Ratio		S.E		C.D
	A	36.00**	0.25660		0.76240
	B	0.56	0.25660		0.76240
	A*B interaction	0.28	0.44444		1.32051

** significant at $p < 0.01$, A: days of storage, B: treatments (P)

P₁, P₂ and P₃ are packaged products of the treatments T₁, T₂, and T₃

$n=3$

be due to small percentage difference of garlic incorporation between the treatments.

Expansion ratio (ER) The expansion ratio was calculated as the cross sectional diameter of the extrudate divided by the diameter of the die opening (Ding et al. 2005). The decrease in the expansion ratio was 3.38, 3.16 and 3.07 D/Do respectively with increase in garlic percentage (0, 5 and 10), as seen in Table 2. This could be due to decrease in rice flour percentage, increase in the garlic percentage and the presence of 30 % defatted soy flour. During the extrusion process, heat and shear facilitate hydration of starches and proteins both classified as structure-forming materials (Guy 2001). Guha and Ali (2006) reported that the glutinous rice was suitable material to produce the expanded extrudate rice product such as ready-to-eat snacks, breakfast cereal with low bulk density, high expansion and low shear stress.

Effect of storage on moisture content of the products

The moisture content of the developed ready-to-eat extruded snacks were estimated during the storage period from 0 to 60th day. There was slight increase in the moisture content of

the products in all the three types of packaging (ordinary, nitrogen and vacuum) which are shown in Table 3. It was also found that during the storage period the moisture content of ordinary packed products was higher (4.037 %) followed by vacuum packed products (3.889 %). The nitrogen packed products showed the lower moisture content (3.629 %). Significant difference in values for moisture content of treatments was seen during storage period from 0 day to 60th day at ($p < 0.01$) level, but, no significant differences were observed between different treatments and the effect of interaction. The moisture content showed an increase from 2.0 % to 5.7 % in ordinary packed products (during storage from 0 to 60 days) and 2.1 % to 4.1 % in nitrogen packed products (during storage from 0 to 30 days) and from 2.1 % to 4.7 % in vacuum packed products (during storage from 0 to 30 days). In nitrogen packed products and vacuum packed products no significant difference was observed from 30th day to 60th day.

Effect of storage life on microbiological load of the product

Values of microbial load and interaction effects among the treatments during storage ($p < 0.01$) were significant. The

Table 4 Effect of storage life on microbiological load of the product

	Treatments	Days of storage			Mean±S.D
		0	30	60	
Ordinary packed products (%)	P ₁	0.000	181.667	226.667	136.11±105.8
	P ₂	0.000	59.333	192.667	84.00±86.8
	P ₃	0.000	30.667	162.333	64.33±74.9
	Mean±S.D	0.00±0.00	90.55±72.09	193.88±32.93	94.81±97.01
		F Ratio	S.E		C.D
	A	279.35**	5.80443		17.24581
	B	40.83**	5.80443		17.24581
	A*B interaction	16.52**	10.05356		29.87063
Nitrogen packed products (%)	P ₁	0.000	83.333	149.000	77.44±66.22
	P ₂	0.000	52.333	118.000	56.77±52.05
	P ₃	0.000	23.000	98.000	40.33±45.24
	Mean±S.D	0.00±0.00	52.88±27.85	121.66±27.75	51.18±61.00
		F Ratio	S.E		C.D
	A	204.84**	4.26248		12.66446
	B	19.03**	4.26248		12.66446
	A*B interaction	4.89**	7.38283		21.93549
Vacuum packed products (%)	P ₁	0.000	94.000	186.33	93.44±81.14
	P ₂	0.000	53.333	106.000	53.11±46.48
	P ₃	0.000	20.333	98.667	39.66±45.55
	Mean±S.D	0.00±0.00	58.88±33.04	130.33±43.26	62.07±65.26
		F Ratio	S.E		C.D
	A	515.08**	2.88104		8.56001
	B	94.36**	2.88104		8.56001
	A*B interaction	27.65**	4.99011		14.82637

** significant at $p < 0.01$, A: days of storage, B: treatments (P)

$n=3$

microbial load of the developed ready-to-eat extruded snacks increased during 60 days of storage, however, the increase was within the limits. Higher microbial load seen in P₁ (control) ordinary packed (136.111 cfu/g), nitrogen packed (77.444 cfu/g) and vacuum packed (93.444 cfu/g) and the lowest microbial load in P₃ ordinary packed (64.333 cfu/g), nitrogen packed (40.333 cfu/g) and vacuum packed (39.667 cfu/g) respectively. A significant increase in microbial load from 0 day (0.000 cfu/g) to 60th day (193.889 cfu/g), (121.667 cfu/g), (130.333 cfu/g) in ordinary packed products, nitrogen packed products and vacuum packed products respectively at $p < 0.01$ level was seen and the interaction effect of the treatments with the storage period was found to be significant at ($p < 0.01$) level as seen in Table 4. The treatments with garlic incorporation showed less microbial load than the control (P₁). It was also found that the microbial load was higher during the storage in ordinary packed products (94.815). There was no significant difference in microbial load between nitrogen and vacuum packed products but these products had low microbial load than the ordinary packed products. Microbial profiles of Modified Atmosphere Packed (MAP) and vacuum packed (VP)-meat did not differ significantly (Narasimha Rao and Sachindra 2002).

Conclusion

From the results of the study, it can be concluded that the garlic can be incorporated in the form of dehydrated powder in rice and defatted soy based ready-to-eat extruded snacks up to 10 % level with acceptable sensory qualities and good physical properties. The products also can be stored for a period of 2 months with minimum changes in moisture content and microbial load proving that garlic acts as an anti-microbial agent in all the three types of packaging that were used in the study. Nitrogen packaging was found to be the best acceptable packing among three types of packaging since crushing of the product was not present. Therefore it can be suggested that garlic powder can be added to the ready-to-eat foods and consumed daily by anyone as it has anti-microbial, anti-helminthic, anti-protozoal, anti-fungal, insecticidal, anti-tumor, anti-thrombotic, anti-cancer, anti-arthritis, hypolipidemic, and hypoglycemic properties.

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