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Effect of Hydrocolloids in the Development of Gluten Free Brown Rice Pasta

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Abstract : Gluten free brown rice pasta is one of the alternatives for celiac disease people who suffer from a nutritional disorder caused by the inability to absorb gluten properly. The brown rice pasta was prepared by 100% replacement of wheat flour by brown rice flour. Hydrocolloids glycerol monostearate (GMS) and xanthan gum were added at the level of 0.5, 1.0, 1.5, 2.0 and 2.5 % individually or in combination with the aim to overcome the structural problems of developed gluten-free brown pasta.Textural analysis, cooking analysis and sensory analysis were carried out to compare the developed gluten-free brown rice pasta with traditional wheat-based pasta. It was observed that the textural, cooking properties and sensory attributes were improved due to synergistic of hydrocolloids 1% GMS and 2% xanthan gum.
Keywords : Brown rice;Celiac disease;Gluten free;Hydrocolloids;Pasta.

Introduction

Pasta, that comprises spaghetti, noodles, vermicelli, macaroni etc., represents a fast-growing segment of the food industry worldwide. As wheat derived staple food, pasta is second only to bread in the world consumption. Its worldwide acceptance is attributed to its low cost, ease of preparation, versatility sensory attributes, long shelf life and easy to transport. Pasta with ideal physical and sensory quality is characterized by strength and elasticity in the dough form, high tensile strength in the dried form, minimal cooking loss and stickiness with good after cooking[1-2]. The special qualities of pasta, high hardness, low adhesiveness, low cooking loss and tolerance to overcooking[3] result from the high gluten content of durum wheat flour, which is mainly responsible for the formation of the matrix structure.

However, some people with a specific genetic nature suffer from celiac disease (or non-tropical sprue) upon consumption of food containing wheat, rye or barley[4]. Celiac disease is a life-long autoimmune enteropathy especially associated with gluten-containing foods like wheat, barley and rye[5]. The patients have intolerance against the gliadin fraction of wheat and the prolamins of rye (secalins), barley (hordeins) and possibly oats (avidins)[6]. Celiac disease affects 1 in 100-200 individuals, predominantly in wheat staple countries .Treatment consists of removal of gluten proteins from the diet, which improves and often eliminates the small intestine pathology. Untreated celiac disease can lead to the development of other autoimmune disorders, as well as osteoporosis, infertility, and neurological conditions[7].

The only effective treatment for CD is strict adherence to a gluten-free diet throughout one's lifetime, which results in clinical and mucosal recovery when followed closely. Rice is a good source for making gluten-free (GF) foods because rice has hypoallergenic properties due to the absence of gliadins [8-9]. Rice flour has many unique attributes, such as bland taste, white color, high digestibility, and hypoallergenic properties In addition, not only it has low levels of sodium and fat but also has low protein levels[7,10]. Brown rice is rich in dietary fibers as well as higher levels of vitamins and minerals than milled white rice. Thus, because only the outermost layer (hull) is removed by milling, brown rice is nutritionally superior [11] to milled white rice. To produce gluten-free pasta with characteristics most similar to semolina pasta, use of brown rice flour will be a good alternative. However, some technological problems can arise in rice pasta production because of the lack of gluten, lending the rice pasta a soft texture [12]. When rice flour is used as the only ingredient for pasta production, it requires additives or particular processing techniques to modify in a suitable way the properties of macromolecular components (starch and proteins), relevant to the structure of the final product [13, 14]. Hydrocolloids, which mimic the viscoelastic properties of gluten, can be applied to improve the quality of pasta with reduced gluten content [15]. Xanthan is widely and more extensively used as a food gum than is any polysaccharide, other than starch, because of its unique and useful properties. The noodles prepared with the addition of GMS showed higher cooking time and lower cooked weight and cooking loss. Texture profile analysis (TPA) of the cooked noodles revealed that the addition of GMS decreased the hardness slightly and the cohesiveness, gumminess, springiness and chewiness to a significant extent[16]. In the present work main aim was to study the effects of GMS and xanthan gum as hydrocolloids individually or in combination for the development of gluten-free brown rice pasta.

Experimental

Raw materials

Commercially available refined wheat flour, used for thepreparation of control pasta was procured from reliable sources of thelocal market of Kolhapur, Maharashtra State, India. Brown rice of variety Sona Masuri was collected from Shri Birla Rice Mill, Ichalkaranji, Maharashtra State, India. The materials were stored at room temperature until further use. Hydrocolloids,Xanthan gum (XG) was procured from Hi-Media Lab. Pvt. Ltd. (Mumbai, India) and commercial food grade Glycerol Monostearate (GMS) was supplied by the Fine Organic Industry, Mumbai,India.

Preparation brown rice flour

The brown rice grains were soaked in water with a ratio to water of 2: 3 (w/w) at room temperature for 4 hours. They were drained and ground by using by pulverizer having hammer mill. The ground rice was dried in an oven at 40 ^{0}C for 24 hours. The flour samples passed through a 70 mesh sieve were stored in a plastic bag at 4 ^{0}C [11].

Formulation used for pasta preparation

Control wheat pasta was prepared by 100% refined wheat flour. Gluten free brown rice pasta was prepared by 100% replacement of wheat flour by brown rice flour. To improve the textural qualities of brown rice pasta, hydrocolloids GMS and xanthangum (XG) were added by 0, 0.5, 1.0, 1.5 and 2.0 % in the brown rice pasta keeping aconstant level of other ingredients.

Table 1 Formulation for pasta preparation

Sample Code	Refined wheat flour (%)	Brown rice flour (%)	GMS (%)	Xanthan gum (%)
Control	100	-	-	-
BR	-	100	-	-
BRG_1	-	100	-	0.5
BRG_2	-	100	-	1.0
BRG_3	-	100	-	1.5
BRG_4	-	100	-	2.0
BRG_5	-	100	-	2.5
BRX_1	-	100	-	0.5

BRX_2	-	100	-	1.0
BRX_3	-	100	-	1.5
BRX_4	-	100	-	2.0
BRX_5	-	100	-	2.5
$BRGX_1$	-	100	1	0.5
$BRGX_2$	-	100	1	1.0
$BRGX_3$	-	100	1	1.5
$BRGX_4$	-	100	1	2.0
$BRGX_5$	-	100	1	2.5

Pasta Processing

The raw materials as per formulation in Table 1 were first mixed at speed of 60 rpm for 10 minutes to facilitate uniform distribution of water to make thedough, which was steamed for 10 minutes to improve texture. The extrusion of this steamed dough was carried out in lab scale pasta Extruder (Atlas Regina, Italy)to get macaroni type of pasta. The extruded pasta samples of various combinations were cut to alength of 5cm and were dried in the tray dryer (Adity Associate, Mumbai, India) for 3 hrs at 100^0C to reduce moisture content. The pasta samples were then allowed to cool to room temperature and then packed in polyethylene covers for storage.

Pasta quality evaluation

Textural and cooking quality evaluation of cooked pasta

Optimal cooking time

An aliquot of pasta sample was cooked in boiling water for anoptimal cooking time (pasta:water ratio = 1:10) without salt addition. The optimum cooking time of pasta was evaluated as the time required for disappearance of the dry central core when gently squeezed between two glass plates[17].

Textural analysis

The dried pasta samples were cooked for their optimal cooking time and analyzed for texture profile using TA-XT Plus Texture Analyzer, Stable Micro System Ltd., London. Texture profile analysis was carried out using probe P/75 (75mm Compression platen), in compression mode at pretest speed 1.00mm/sec, test speed 5.00mm/sec, post-test speed 5.00mm/sec. Target mode was kept at 40.00% strain and trigger force 5.0g. Data acquisition rate was kept at 200.00 pps. Three tests for each sample were carried out to obtain mean value [18].

Cooking loss

Cooking water collected from each sample was evaporated to constant weight in an oven at 105 ^0C. The residue was weighed and reported as a percentage of the original dry pasta sample, according to approved method of cooking loss[19].

Sensory evaluation of cooked pasta

For sensory evaluation, the samples were boiled using tap water at anoptimum cooking time. Sensory evaluation of these identically coded cooked samples was carried out by a panel of 10 judges for different sensory attributes like appearance, texture, colour, taste, bite, stickiness, mouth feel, overall acceptability using nine-point hedonic scales, where 9= Extremely like and 1= Extremely dislike[20].

Functional properties of pasta

Water absorption index (WAI) and Water solubility index (WSI) of pasta

The water absorption index (WAI), water solubility index (WSI) were measured according to the standard reported method by [21] with minor modifications. Each sample (1 g) of ground pasta was suspended in 20 ml of distilled water in a 50 ml centrifuge tube and stirred with aglass rod, put in water bath for 30 min at 30 °C temperature. Subsequently, the dispersions were centrifuged at 2000rpm for 10 min using a centrifuge (Remi Q-8C, India). The supernatants were poured into dry test tubes and stored overnight at 110 °C for the process of evaporation.

WAI and WSI were calculated using following equations

WAI (g/g) = Weight of sediment /Weight of dry solids

WSI (%) = Weight of dissolved solids in supernatant/ Weight of dry solids) x 100

Bulk density of pasta

Bulk density was determined as per themethod of Benhur*et al*., 2015[21] by filling a 1-litre measuring cylinder with the pasta with less than 12% moisture slightly above the liter mark. The cylinder was tapped 10 times till the products measured up to the liter mark. The weight of the pasta was taken and bulk density was calculated with the formula

Bulk density (g/ml) = Weight of the sample (g)/ Volume of the sample after tapping (ml)

Statistical analysis

Analysis of variance (one-way ANOVA), followed by Turkey's test ($p<0.05$) with Minitab 16 software (Minitab Inc., USA), were used for statistical analysis. Results from all the tests were obtained as means ±SD.

Results and Discussion

Effect of hydrocolloids on the textural and cooking properties of gluten-free brown rice pasta

For good quality of pasta, the primary parameters are hardness, springiness, and cohesiveness which should be higher, whereas the secondary parameters are chewiness and resilience.

Statistical analysis of pasta sample indicated that the textural properties hardness, springiness, cohesiveness, chewiness, and resilience were significantly affected ($p<0.05$) due to theaddition of hydrocolloids in pasta samples. From Table 2, it could be observed that, as the GMS level increased from 0% to 2.5%, the hardness of gluten free brown rice pasta increased from 70.33 gf to 117.93 gf which was more pronounced up to 1% level of GMS (BRG_2), but it was less than the control wheat pasta sample having hardness 141.72 gf.The hardness of brown rice pasta increased with theaddition of xanthan gum from 70.33 gf to 227.98 gf. Due to thesynergistic effect of 1% GMS and increasing level of xanthan gum from 0% to 2.5%; hardness still increased up to 252.36 gf for gluten free brown rice pasta which was much more than the control pastasample.

Wang *et al.,* 2011[22] observed that with increasing level of GMS from 0.25% to 2.0% hardness increased. This could be due to improvement in structural characteristics of brown rice as GMS have very good characteristics of emulsifier [23, 24].Comparative outcomes have been observed by Edwards *et al*., (1995)[25] demonstrating a change in pasta firmness without the adjustment of cooking qualities when xanthan gum was included at levels of 1% or 2%. This may be because of the development of a system by the soluble fiber around the starch granules, prompting to a more cohesiveness between starch and protein within pasta structure [26].

Similar to hardness, chewiness also increased from 21.55 to 32.05with theaddition of GMS from 0% to 2.5% in gluten free brown rice pasta but it was less than the control sample having chewiness 91.626. With increasing level of xanthan gum alone from 0% to 2.5%, the chewiness increased from 21.55 to 132.19 for gluten free brown rice pasta whereas,with 1% GMS, it was still increased up to 154.19 for gluten free brown rice pasta which were much more than the control sample.

Springiness, cohesiveness, and resiliencewere very little affected by theaddition of hydrocolloids in gluten free brown rice pastaindividually or in combination.

The cooking loss is one of the important parameter used by the industry, researcher or consumer for checking the qualities of pasta. The cooking loss reduced from 16.2% to 13.15% with increasing level of GMS from 0% to 2.5% in gluten-free brown rice pasta. Kim *et al*., 1989[27] also reported that addition of 1% GMS lowered the cooking loss and improved the firmness. This could be due to GMS-amylose complex formation during cooking which reduced the extent of solubilization of starch molecules upon heating during in water which resulted in adecrease in cooking loss. Pournima *et al*., 2015[28] observed that increased level of GMS to pasta product lowered the cooking loss and enhanced the final quality characteristics of the product. Kaur *et al*., 2005 [29] reported that the increased level of GMS lowered the cooked weight as well as cooking loss of the noodles made using corn and potato starch. The presence of GMS might have controlled the swelling of starch granules to their full degree and movement of water that brought down cooking weight. The lower cooking losses with GMS demonstrated its complexation with amylose inside the cooked noodles.

It was observed that cooking qualities of gluten free brown rice pasta were increased with increasing level of xanthan gum alone or with 1% GMS. Cooking loss decreased from 16.2% to 7.13% for gluten free brown rice pasta with increasing level of xanthan gum from 0.0% to 2.5%. Synergistic effect of xanthan gum and GMS still decreased cooking loss upto 6.3 % which was comparable to the control sample. These results were in the range of the ideal expected cooking loss values which are 7–8% for pasta[30, 31].Similarly, Yalcin Seda and Basman Arzu, 2008[32] reported that the rice noodle samples including Xanthan gum had better cooking and sensory properties.

Table 2: Effect of hydrocolloids on the textural properties of gluten-free brown rice pasta

Sample	Hardness(gf)	Springiness	Cohesiveness	Chewiness	Resilience	Cooking loss (%)
Control	141.72±0.2^{h}	0.95±0.02^{d}	0.67±0.01^{b}	91.62±0.67^{f}	0.45±0.02^{b}	6.20±0.14^{i}
BR	70.33±0.11^{m}	0.79±0.01^{fg}	0.46±0.01^{e}	21.55±0.99^{n}	0.22±0.03^{g}	16.20±0.22^{a}
BRG$_1$	93.49±0.12^{l}	0.76±0.01^{g}	0.47±0.07^{e}	25.81±0.91^{m}	0.27±0.01^{fg}	15.10±0.14^{b}
BRG$_2$	114.06±0.57^{k}	0.88±0.04^{e}	0.47±0.06^{e}	30.03±0.12^{l}	0.30±0.04^{fg}	13.42±0.22^{c}
BRG$_3$	116.42±0.25^{j}	0.80±0.03^{f}	0.46±0.04^{e}	30.83±1.11^{j}	0.31±0.02^{ef}	13.25±0.10^{c}
BRG$_4$	117.03±0.88^{ij}	0.81±0.18^{ef}	0.44±0.22^{e}	31.35±0.75^{ij}	0.32±0.11^{def}	13.19±0.21^{c}
BRG$_5$	117.93±0.91^{i}	0.88±0.08^{e}	0.45±0.02^{e}	32.05±0.77^{i}	0.33±0.01^{def}	13.15±0.11^{c}
BRX$_1$	93.14±0.50^{l}	0.88±0.01^{e}	0.46±0.05^{e}	38.15±0.20^{k}	0.27±0.12^{fg}	9.50±0.12^{e}
BRX$_2$	190.66±0.48^{e}	0.98±0.03^{bc}	0.59±0.05^{c}	95.66±0.21^{e}	0.32±0.13^{ef}	7.95±0.13^{g}
BRX$_3$	179.54±0.77^{f}	0.90±0.07^{e}	0.58±0.01^{c}	111.22±0.35^{d}	0.32±0.05^{ef}	7.30±0.08$_{h}$
BRX$_4$	221.98±0.08^{d}	0.99±0.09^{bc}	0.56±0.09^{cd}	129.49±0.42^{c}	0.37±0.04^{cde}	7.15±0.15^{h}
BRX$_5$	227.77±0.20^{c}	1.11±0.04^{bc}	0.77±0.02^{a}	132.19±0.25^{b}	0.59±0.08^{a}	7.13±0.12^{h}
BRGX$_1$	147.98±0.47^{g}	0.78±0.09^{fg}	0.31±0.05^{f}	36.80±0.12^{k}	0.38±0.09^{bcde}	11.35±0.13^{d}
BRGX$_2$	148.81±0.65^{g}	0.98±0.01^{cd}	0.53±0.06^{d}	50.72±0.36^{ij}	0.39±0.04^{bcde}	11.07±0.14^{d}
BRGX$_3$	220.44±0.87^{d}	1.02±0.07^{b}	0.68±0.05^{b}	71.65±0.98^{h}	0.41±0.05^{bcd}	8.95±0.25^{f}
BRGX$_4$	247.51±0.90^{b}	0.89±0.06^{e}	0.58±0.08^{c}	87.44±0.24^{g}	0.42±0.03^{bc}	6.35±0.12^{i}
BRGX$_5$	252.36±0.51^{a}	0.80±0.09^{f}	0.45±0.05^{e}	154.19±0.15^{a}	0.43±0.16^{bc}	6.30±0.16^{i}

Data are means of three replicate trials. Within the same column, the values with the different letter are significantly different ($p<0.05$)

Effect of hydrocolloids on the sensory attributes of gluten free brown rice pasta

The sensory analysis is very much important analysis as it gives anidea regarding consumer acceptance of sample. With theaddition of hydrocolloids in brown rice pasta, there was anincrease in acceptance level due to improvement in textural properties of pasta.

With the addition of GMS from 0% to 2.5% in gluten-freebrown rice pasta, there was development in textural characteristics of pasta. There was animprovement in texture as well as appearance with theaddition of GMS as shown Figure 1, but it was limited by stickiness and taste. Overallupto 1**%** level of addition of GMS (BRG_2) in gluten free brown rice pasta was accepted as per sensory analysis for brown rice pasta.

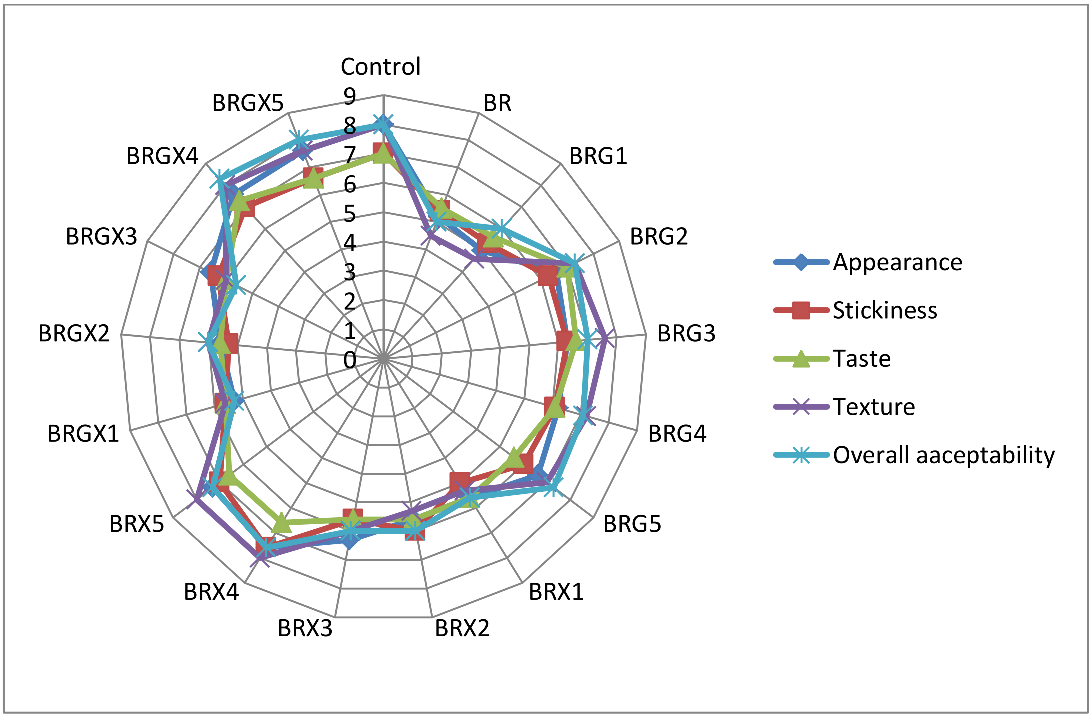

Figure 1: Effect of GMS on the sensory attributes of gluten free brown rice pasta

Scores regarding appearance, texture, overall acceptability were increased with theaddition of xanthan gum in gluten free brown rice pasta upto 2% level of xanthan gum (BRX_4) as shown in Figure1. These sensory attributes scores were even more when xanthan gum upto 2% was added with 1%GMS in gluten free brown rice pasta ($BRWGX_4$), but after that as thetexture was too hard so it was less accepted as per the sensory analysis. So based on the sensory analysis 1% GMS and 2% xanthan gum in gluten free brown rice pasta ($BRGX_4$) wasoptimized.

Effect of hydrocolloids on functional properties of gluten-free brown rice pasta

Water absorption index (WAI) and Water solubility were significantly affected ($p<0.05$) by theaddition of hydrocolloids.

With increasing level of GMSfrom 0% to 2.5% in gluten-free brown rice pasta, water absorption index (WAI) increased from 6.01 g/g dry solids to 6.86 g/g dry solids as shown in Table 3. The increase in WAI could be due to the decline in starch fragmentation due to the decline in friction due to its lubrication action in the extruder barrel[33]. But Wang *et al*.,2011[22] reported that WAI of the GMS extrudates decreased from 4.36g/g to 3.51 g/g, which was less than control (4.61 g/g).

Water absorption index (WAI) decreased with increasing level of xanthan gum only or xanthan gumwith GMS. It decreased from 6.44 g/g dry solids to 4.06 g/g dry solids for gluten free brown rice pasta with increasing level of xanthan alone from 0% to 2.5%. Similarly synergistic effect of 1% GMS and increasing level of xanthan gum from 0% to 2.5%, decreased WAI from 5.26 g/g dry solids to 4.94g/g dry solids.This could be due to theprevention of leaching of amylose during gelatinization due to complex structure created by xanthan gum alone or with GMS [22].

With increasing level of GMS from 0% to 2.5% in gluten-freebrown rice pasta, water solubility index (WSI) decreased from 11.52% to 6.32%.Water solubility index (WSI) increased with increasing level of xanthan gum alone or with GMS. It increased from 8.71% to 11.52 % for gluten free brown rice pasta having xanthan only or with GMS as shown in Table 3.This could be because of the formation and dissociation of amylose-lipid complexes [34].

Table 3: Effect of hydrocolloids on the functional properties of gluten-free brown rice pasta

Sample Code	WAI (g/g dry solids)	WSI (%)	Bulk Density (%)
Control	3.89 ± 0.22^{i}	4.51 ± 0.41^{m}	0.53 ± 0.31^{a}
BR	6.01 ± 0.14^{c}	11.52 ± 0.35^{a}	0.50 ± 0.16^{a}
BRG_1	6.12 ± 0.13^{c}	10.49 ± 0.36^{f}	0.49 ± 0.18^{a}
BRG_2	6.44 ± 0.25^{b}	8.71 ± 0.11^{j}	0.48 ± 0.21^{a}
BRG_3	6.58 ± 0.36^{ab}	7.97 ± 0.33^{k}	0.5 ± 0.31^{a}
BRG_4	6.70 ± 0.22^{ab}	6.02 ± 0.18^{k}	0.49 ± 0.32^{a}
BRG_5	6.86 ± 0.45^{a}	6.32 ± 0.25^{l}	0.48 ± 0.54^{a}
BRX_1	4.56 ± 0.04^{f}	8.87 ± 0.13^{i}	0.48 ± 0.16^{a}
BRX_2	4.34 ± 0.12^{fg}	9.32 ± 0.14^{h}	0.49 ± 0.17^{a}
BRX_3	4.27 ± 0.10^{gh}	10.24 ± 0.24^{g}	0.48 ± 0.24^{a}
BRX_4	4.31 ± 0.02^{fg}	11.09 ± 0.12^{cd}	0.5 ± 0.12^{a}
BRX_5	4.06 ± 0.20^{hi}	11.52 ± 0.30^{a}	0.48 ± 0.14^{a}
$BRGX_1$	5.26 ± 0.30^{d}	11.32 ± 0.24^{b}	0.51 ± 0.25^{a}
$BRGX_2$	5.19 ± 0.2^{de}	11.15 ± 0.21^{c}	0.48 ± 0.12^{a}
$BRGX_3$	5.14 ± 0.8^{de}	10.98 ± 0.10^{d}	0.52 ± 0.12^{a}
$BRGX_4$	5.05 ± 0.12^{de}	10.86 ± 0.12^{e}	0.53 ± 0.03^{a}
$BRGX_5$	$4.94\pm0.03^{e10.98}$	10.78 ± 0.36^{e}	0.51 ± 0.05^{a}

Data are means of three replicate trials. Within the same column, the values with the different letter are significantly different (p<0.05)

Bulk density was not significantly affected (p>0.05) by theaddition of hydrocolloids in gluten free brown rice pasta individually or in themixture. It was in the range of 0.4% to 0.5 %.

Conclusion

Hydrocolloids GMS and xanthan gum individually or in combination helped to improve the textural, sensory and functional properties of gluten-free brown rice pasta. Based on the textural analysis,cooking analysis and sensory analysis; up to 1% level addition of GMS in gluten free brown rice pasta made a significant difference. So 1% GMS level was optimized to study the synergistic effect of hydrocolloids GMS and xanthan gum. Addition xanthan gum individually improved the texture and ultimately sensory analysis of gluten free brown rice pasta, but not comparable with the control pasta. But the synergistic effect of 2% xanthan gum with 1%($BRGX_4$) GMS, improved the textural, cooking, sensory and functional properties of gluten-free brown rice pasta and was comparable with control pasta.

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