Effect of Alternative Hydrocolloids in Gluten Free Chickpea Pasta

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SUMMARY

Legume pasta is a sustainable product that improves the nutritional quality of food pyramids. This study evaluates the use of alternative hydrocolloids in the production of gluten free chickpea (*Cicer arietinum L.)* pasta. The cooking quality and the texture of chickpea pasta made with gledis (*Gleditsia triacanthos*) gum and brea (*Cercidium praecox)* gum were determined and compared to those actually used in the food industry. The pasta made with gledis and brea had similar physiochemical qualities as pasta made with xanthan gum and carboxy methilcellulose. The firmness achieved with gledis was higher than the other hydrocolloids. For further studies, a sensory analysis was done and sensorial attributes of pasta were similar in all samples. Pasta made with gledis was preferred. Alternative hydrocolloids can be used in the emerging gluten free pasta industry with same cooking quality and texture than those actually used. The studies of these hydrocolloids should be extended to other food products.

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Introduction

Pasta is usually made with wheat (*Triticum durum*) semolina and its nutritional profile is high in starch and low in protein and fibre, whereas chickpea (*Cicer arietinum L.*) is a cheap source of amino acids, essential fatty acids, slowly digestible starch, and fibre. Gluten free (GF) pasta is actually widespread consumed due to its affordability, easy-to-cook features, and its healthy qualities. In countries without a legume consumption habit, substituting cereals in dietary nutrition could improve daily access to a balanced diet. The consumption of legumes reduces the chances of contracting chronic health problems such as obesity, cardiovascular diseases and diabetes, which improves human health and well-being (Bresciani et al., 2021). Legume-based foods are an important source of prebiotics carbohydrates like the raffinose family of oligosaccharides (RFOs). These prebiotics are fermented in the colon by favorable gut microorganisms. They produce short fatty acids which promote the growth of beneficial bacteria and consequently, reduce the pathogenic bacteria population (Losano Richard et al., 2021).

Considering global warming and the future of food production, chickpea crops have a positive effect on soil, fixing nitrogen through a symbiotic relation between root and rhizobium bacteria. In addition, chickpea is adapted to semi-arid regions where access to food is limited. With legume production there is high potential to simultaneously improve the environmental sustainability and the nutritional quality of food chains (Saget et al., 2020).

Nowadays 1 % of the world population is affected by celiac disease, characterized by alterations in the digestive system when they consume products with gluten (Lancetti et al., 2020). Gluten in food forms a three-dimensional viscoelastic network that traps starch molecules during gelatinization. For people with celiac disease, the only solution is a lifelong GF diet (Sciarini et al., 2010). In addition, gluten substitution is a major concern for the food industry. Demand and consumption of GF products is increasing, turning the GF food market from a specialty niche to a trend in the global food sector.

Hydrocolloids are hydrophilic, high molecular weight biopolymers with the ability to increase the viscosity of their suspensions (Sciarini et al., 2009). The absence of gluten in pasta made with legumes can affect cooking and texture quality. In order to improve physical quality increasing water absorption and reducing cooking losses, hydrocolloids such as xanthan gum (XG) and carboxymethyl cellulose (CMC) are used (Srikaeo et al., 2018). The exploration of innovative natural sources of additives, produced locally that increase the physical-chemical quality of pasta is very important for the development of the food industry committed to the local environment. One of them is brea gum (BG) which is a hydrocolloid extracted from the exudate of the *Cercidium praecox* tree. Up to 75% of this acidic polysaccharide is made up of hydrolysable sugars, such as D-xylose, L-arabinose, 4-O-methyl-D-glucuronate and D-glucuronic acid (Spotti et al., 2016). These tree has the ability to repopulate deserted areas and colonize degraded land and it is a vital economic source for small producers in the semi-arid region of Chaco, Argentina (Masuelli et al., 2018). The other hydrocolloid is gledis gum (GG) which is extracted from the seeds of the *Gleditsia triacanthos* tree. Originally from North America and Central Europe, it has been widely spread in Argentina. This gum is a polysaccharide rich in galactomannan, with a variable galactose:mannose (Gal:Man) ratio. Three different types of galactomannans were observed on GG and their potential use in the food industry has been studied (Loser et al., 2021). The objective of this study was to assess the physicochemical and texture effect of alternative hydrocolloids and those used in the current food industry in gluten free chickpea pasta (CP) production.

Materials and methods

Materials

Dry chickpea grains were obtained from a processing facility based in Colonia Caroya, located in Córdoba, Argentina. To ground the grains into a fine flour, a FOSS cyclone mill was utilized (Hillerod, Denmark) equipped with a 0.5 mm sieve. Xanthan gum and Carboxymethil Cellulose were supplied by Pura Química S.A. (Córdoba, Argentina). In order to obtain *G. triacanthos* seeds, the pods were handpicked from trees in Córdoba, Argentina. Then, the seeds went through a mechanical process to be separated from the pods and afterwards they were manually cleaned and classified. Using a hammer mill, the seeds were then grounded (Fritsch, Germany) (Barrera et al., 2013)**.** Brea exudate was obtained from trees located in the Natural Reserve of Chancaní (Córdoba, Argentina) and stored at room temperature until used.

Methods

Hydrocolloids extraction

GG was extracted from *G. triacanthos* grains with ethanol and hot water precipitation, pursuant to Loser et al., (2021). BG was obtained after the purification process which includes the following steps: 1—grinding, 2—dissolving, 3—decanting, 4—filtrating, 5—bleaching, 6—drying (Masuelli et al., 2018). A hot dry oven (Memmert 600) was used to slowly dry the material that had previously precipitated (35 ± 3 °C during 10 hs) and then it was grinded with a cyclone mill (Ciclotec™). Finally, the powder that was extracted was used for the experiments without pre-treatment. Both hydrocolloids were stored at ambient temperature.

Water Absorption Index (WAI)

The water absorption index was evaluated in duplicate to determine the amount of water needed in each suspension of flour and hydrocolloid used to prepare CP, following the procedure of Loubes et al., (2016) with some modifications. To explain briefly, 2.5 g of flour and hydrocolloids specimens (1 and 2 % w/w) were measured into calibrated centrifuge tubes with a 50 mL capacity. Afterwards, distilled water (10 mL) was added and mixed for 30 min at 1000 RPM. The tubes were centrifuged at 3000*g* during 10 min. The weight of the sediment was measured to determine:

WAI (g/g) = wet sediment weight / dry sediment weight

Viscosity analysis

The pasting properties were measured in suspensions made from chickpea flour as control and chickpea flour added with 1% and 2% of hydrocolloids utilizing a Rapid Visco Analyzer (RVA) (Warriewood, Australia). Analyses of the results were done using Thermocline software of Perten Instruments (Macquarie Park, Australia). By virtue of the standard Newport Scientific Method 1 (STD1) the parameters peak viscosity (PV), trough viscosity (T), breakdown (B=PV–T), final viscosity (FV), setback (S=FV–T), and pasting temperature (PT) were calculated in duplicate

Pasta Production

-Mixing: CP was made as described previously by Palavecino et al., 2017. Water was added based on the WAI of the mixtures. Following the procedure of Motta Romero et al., (2017) two different concentrations of hydrocolloids (1 and 2 %) were used and compared with a control sample without additives to explore the presence and influence of increasing concentration on the pasta quality. By means of a domestic extruder pasta machine (FP 4070, ATMA, Argentina) the CP was elaborated as follows. 50 g of the dry ingredients were added to a large bowl and to that the appropriate amount of water for each sample (about 20 mL, based on dough WAI) was incorporated. Everything was mixed for about 3 min. Once the dough was obtained, it was pushed through the extruder cavity with a spaghetti attachment with a diameter of 2 mm.

-Drying: As reported previously (Bustos et al., 2011) the CP was then dried in two steps, the first one it was dried in an air convection drier for 30 min at 30 °C without controlling humidity; the second step was carried out at 45 °C in a humidity-controlled (75%) drier over 17.5 hs.

-Storage: The samples were stored in heat-sealed plastic inside airtight containers at room temperature.

-Cooking procedure

4 g of CP were broken into 5 cm pieces and cooked in 200 ml of distilled boiling water. The water was kept at a boiling point during the whole cooking process. The Optimum Cooking Time (OCT) was determined according to the method AACC 16-50 (AACC, 2000) in concordance with the moment in which the inner white core of the CP had disappeared. Right after cooking and draining the samples, an analysis to identify cooking losses and water absorption was carried out.

Technological Pasta Quality

-Cooking losses

Cooking loss was evaluated by stating the amount of solids that were lost in cooking water according to the standard method AACC 66-50.01 (AACC, 2000).

-Water absorption

The increase in CP weight due to cooking was expressed as the ratio percentage between the weight increase and the weight of uncooked CP. (Bresciani et al., 2021)

-Colour

The colour of 5 pieces of dry CP with a 3 cm width was stated using a CM-700d/600d KONICA MINOLTA spectrophotometer (Ramsey, USA). The results were represented as CIE L*a*b*(Pathare et al., 2013).

-Confocal laser scanning microscopy

Surface roughness images of raw and cooked CP were obtained using a LEXT OLS4000 Olympus confocal laser (Tokyo, Japan).

Texture profile

The texture in dry and cooked pasta was evaluated applying an Instron Universal Testing Machine (Model 3342, Norwood, MA, USA) equipped with a 500 N cell. For instrument operation and data collection, Bluehill software (Instron, U.S.A.) was used.

-Dry pasta fracturability

Pasta fracturability was achieved following the procedure of Bulletin et al., (2020) where a single piece of raw CP was cut at a speed of 3 mm/s using an aluminum break probe with a three point bend rig. The maximum force required to cut the CP was recorded as the fracturability. The measurements were done in quadruplicate.

-Cooked pasta texture

A texture profile analysis (TPA) test was executed according to Palavecino et al., (2017). At a test speed of 50 mm/min and a trigger force of 0.05 N, the evaluation consisted of 2 compression cycles at 30% of the original height. In this essay TPA parameters such as hardness (g), cohesiveness, springiness (cm), gumminess (N), and chewiness were calculated from the force-time curve (El-Sohaimy et al., 2020).

Sensory evaluation

Based on the results obtained in the technological quality evaluations, the sample of CP made with Xanthan Gum and described above which is currently used industrially in the production of CP was chosen to compare with the gums under study. Briefly, three pasta samples: CP made with xanthan gum (XGCP), CP made with gledis gum (GGCP) and CP made with brea gum (BGCP) were assessed by a panel of 25 evaluators (15 women and 10 men) aged between 23 and 58 years old with experience in sensorial analysis. Attributes were measured in a hedonic scale for consumer acceptability test of scores from 1 to 9 and increased with quality. The samples were served in a plastic pot randomly named with a three-digit code. During daytime it was possible to assess some of the following parameters by means of manipulating the samples using the hands: Surface stickiness (the way two pieces of cooked spaghetti stick together when separated) and elasticity (the extent to which a piece of cooked spaghetti returns to its original length when stretched). Afterwards, some other textural parameters were evaluated also in daylight by force of manipulating the samples in the mouth: Firmness (the force that is required to break through the spaghetti using only the front teeth) and chewiness (the number of times it takes to chew the spaghetti until it is swallowed). Evaluators were given some water to rinse between samples. The panelists were not given any information about the coded samples. In addition, an order of preference test was realized. The panel assigned a number to each sample, where 1 was the most liked and 3 the least liked.

The Friedman test was performed to establish if there were significant differences between the samples. The T Friedman statistical function was useful to delimit the differences between samples (Armellini et al., 2018).

Statistical analyses

Both the production of CP and the evaluation of its quality were performed in quadruplicate. The results are shown as mean value and their standard deviation. An analysis of variance (ANOVA) was performed, followed by a pairwise comparison using Fisher's least significant difference (LSD) procedure. It was possible to determine significant difference only when P Value was lower than 0.05. All of the statistical evaluation was calculated utilizing the software Infostat (Córdoba, Argentina).

Results and discussion

Samples Characterisation

Previous to producing CP, WAI was useful to adjust the water needed to obtain the same dough consistency based on the control consistency. As it can be seen in Table 1, all the suspensions adsorbed different ($P > 0.05$) quantities of water. WAI of suspensions increased when concentration of hydrocolloids was higher ($P > 0.05$). CMC adsorbed more water than the other hydrocolloids. The main reason for these differences is the interaction between water and hydrocolloids. CMC is a cellulose-derived molecule that makes starch granules adhere to one another and gives more space to entrap water in the system. (Culetu et al., 2021).

Pasting properties

The results of the rapid visco analyser (RVA) are present in Table 2. Control samples did not differ significantly from the other samples. This could be due to the influence of the size and shape of the chickpea starch during controlled gelatinization. In all cases, a higher concentration of hydrocolloids increased breakdown and decreased peak time. When the XG concentration was increased, the pasting temperature increased significantly ($P> 0.05$). Final viscosity indicates the ability of the suspensions to form a viscous paste. RVA analyses were performed heating the mixture in presence of water and, in this process, gelatinization took place. After this process temperature decreased and the complex of amylose-hydrocolloids formed increases final viscosity. CMC final viscosity was significantly higher than others. The capacity of CMC to absorb more water shows that CMC reduces water availability in the matrix, increasing the final viscosity.

Cooking Quality

The results obtained after cooking the CP with 1 and 2 % of hydrocolloids added are shown in Table 3. The OCT for all the samples was determined as 8 min. All the hydrocolloids concentrations lost less solids than the control. The gelatinization of starch takes place while cooking the CP. During this process, solids lixiviates to the water. Hydrocolloids act as a barrier and retain more solids into the matrix. A special increase of GG showed significantly less cooking losses. GG molecules are conformed by galactomannans, which they would seem to entrap the starch granules inside their entanglement polymer network reducing the lixiviation of solids (Loser et al., 2021). As observed in Table 4, in all the samples an addition of hydrocolloids significantly affected a* and b* colour parameters. Culetu et al., (2021) reported the change in colour of GF pasta using hydrocolloids but in this case, observing a change in luminosity. The Figures 1 and 2 show the surface of raw and cooked CP without hydrocolloids. Compared with raw CP, significant alternations were noticed in the CLSM images of the cooked CP, the starch granule that was originally intact in the raw CP was entirely swollen in cooked CP (Jia et al., 2020). As it can be observed after the cooking procedure, solids are lixiviated and distributed in the matrix.

Texture analysis

Fracturability results of raw CP with different concentration of hydrocolloids can be observed in Table 5. Compression values of CP increased when hydrocolloids were added. The XGCP expressed the highest compression energy required to fracture the piece, while GGCP and CMC chickpea pasta (CMCCP) were very close. High energy required to cut the pasta is associated with better pasta quality considering less breakage susceptibility of the pasta into shorter pieces during transport and storage (Martinez et al., 2014). When the hydrocolloid concentration increased, a higher compression force was needed to fracture the CP.

Results of cooked CP firmness are shown in Table 6. Firmness was significantly affected with the addition of hydrocolloids. GG showed the higher firmness at 1 and 2% of addition, where there was a better interaction between galactomannans and proteins/starch granules of chickpea flour, thus contributing to the development of a CP with a stronger or more interconnected microstructure that results in a firmer cooked CP. Kaur et al., (2015) made a similar observation when guar gum, which has a similar chemical composition to GG, was used. In this case, guar gum increased the swelling ability of the corn and mung starch granules, possibly by inhibiting the leaching of the starch components during gelatinization, resulting in a higher viscous system. XG also expressed firmness during TPA test. CMCCP had the lowest firmness out of all the hydrocolloids, and simultaneously, it was the CP that absorbed the most water after cooking, proving that excess in water absorption is counter-productive to CP texture quality.

Sensory evaluation

Friedman's test demonstrated statically that sensory attributes did not vary significantly between the CP samples. On the other hand, as it can be seen in Table 7, the order of preference showed that the panellists preferred CP made with GG.

Conclusions

Gluten free chickpea pasta could be made using alternative hydrocolloids with a similar quality to those actually used in the food industry. Water absorption of hydrocolloids during mixing affects pasta quality. Increasing hydrocolloid concentrations from 1 to 2 % during chickpea pasta analysis allows us to obtain additional information in the evaluation findings. Interaction between chickpea flour and hydrocolloids during gelatinization affects viscosity profile. Paying special attention to those made with *Gleditsia triacanthos* gum, providing excellent attributes in texture and sensory analysis. More research should be done using these additives in other food products.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethical approval

Ethics approval was not required for this research.

Conflict of interest

The authors declare that they have no conflicts of interest.

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In this study the author analyze the texture of gluten free sorghum noodles elaborated with different additives. Evaluating the relationship between firmness and the network matrix strenght. In this article we based the methodology and instrumental for pasta production and texture analysis of coocked chickpea pasta.

- Culetu, A. Duta, ED., Papageorgiou, M., & Varzakas, T. (2021). *The Role of Hydrocolloids in Gluten-Free Bread and Pasta; Rheology, Characteristics, Staling and Glycemic Index*. 1–19.

In this study, Culetu compares the use of different commercial hydrocolloids in gluten-free bread and pasta. This research allows us to understand the influence of hydration and the interaction of ingredients during pasta production.

- Loser, Ú., Iturriaga, L., Ribotta, P. D., & Barrera, G. N. (2021). Combined systems of starch and Gleditsia triacanthos galactomannans: Thermal and gelling properties. *Food Hydrocolloids*, *112*(September 2020), 106378. https://doi.org/10.1016/j.foodhyd.2020.106378

The present study provides a theoretical basis for the interaction between gledis gum galactomannans and starch, the main component of chickpea flour. It also helps us to know the chemical structure of gledis gum and compare it with similar hydrocolloids.

- Kaur, A., Shevkani, K., Singh, N., Sharma, P., & Kaur, S. (2015). Effect of guar gum and xanthan gum on pasting and noodle-making properties of potato, corn and mung bean starches. *Journal of Food Science and Technology*, *52*(12), 8113–8121. https://doi.org/10.1007/s13197-015-1954-5

This article contributes to our research by allowing us to know the activity of commercial hydrocolloids with a structure similar to gledis gum. Working with a pasta made with mung beans, a legume similar to chickpeas. Also, it helped us better describe our control sample made with xanthan gum.

- Martinez, C. S., Ribotta, P. D., Añón, M. C., & León, A. E. (2014). Effect of amaranth flour (Amaranthus mantegazzianus) on the technological and sensory quality of bread wheat pasta. *Food Science and Technology International*, *20*(2), 127–135. https://doi.org/10.1177/1082013213476072

Martínez studied the susceptibility to breakage during transport evaluated in terms of the fracturability of the raw pasta. A higher energy to fracture the raw pasta was evidenced in the GGCP samples. Representing a positive characteristic for the food industry.

Table 1. Water absorption index of suspensions as a function of hydrocolloid concentration

	Suspension with 1% of hydrocolloids	Suspension with 2% of hydrocolloids
Sample	**WAI**	**WAI**
BG	1.98 ± 0.04 ab	2.07 ± 0.02 b
CMC	2.11 ± 0.10 b	2.38 ± 0.01 d
GG	2.00 ± 0.02 ab	2.20 ± 0.03 bc
XG	2.02 ± 0.04 ab	2.33 ± 0.02 cd
Control	1.89 ± 0.13 a	1.89 ± 0.13 a

Mean±SD; different letters within a column indicate significant differences ($p<0.05$). BG, *Brea* gum; CMC; Carboxi Metil Cellulose; GG, *Gleditsia triacanthos* gum; XG, Xanthan Gum.

Table 2. Values for pasting properties of chickpea flour with different hydrocolloids

Sample	Peak 1	Trough 1	Breakdown	Final Visc	Setback	Peak Time	Pasting Temp
	Suspension with 1% of hydrocolloids						
BG	1292 ± 6.36 b	1202 ± 4.95 b	90 ± 1.41 b	1600 ± 24.04 a	397 ± 19.09 a	5.04 ± 0.05 a	74.73 ± 0.6 a
CMC	1473 ± 38.18 c	1432 ± 36.77 c	41 ± 1.41 a	2116 ± 62.93 c	684 ± 26.16 c	7.00 c	77.18 ± 0.53 cd
GG	1302 ± 19.09 b	1230 ± 52.33 b	72 ± 33.23 ab	1661 ± 28.28 ab	431 ± 24.04 a	6.34 ± 0.09 b	75.45 ± 0.49 ab
XG	1184 ± 14.85 a	1110 ± 12.73 a	74 ± 2.12 ab	1715 ± 28.99 b	605 ± 16.26 b	5.17 ± 0.05 a	77.93 ± 0.67 d
Control	1324 ± 0.71 b	1263 ± 2.83 b	61 ± 2.12 ab	1673 ± 11.31 ab	410 ± 8.49 a	6.17 ± 0.14 b	76.23 ± 0.53 bc
	Suspension with 2% of hydrocolloids						
Sample	**Peak 1**	**Trough 1**	**Breakdown**	**Final Visc**	**Setback**	**Peak Time**	**Pasting Temp**
BG	1257 ± 15.56 a	1140 ± 14.14 ab	117 ± 1.41 b	1457 ± 16.97 a	317 ± 2.83 a	4.9 ± 0.04 a	76.68 ± 0.04 ab
CMC	1771 ± 122.33 b	1682 ± 124.45 c	89 ± 2.12 ab	2808 ± 190.21 c	1126 ± 65.76 e	6.9 ± 0.14 d	77.08 ± 0.53 b
GG	1205 ± 23.33 a	1097 ± 6.36 a	108 ± 16.97 b	1665 ± 1.41 ab	567 ± 7.78 c	5.67 ± 0.09 b	75.88 ± 0.04 a
XG	1217 ± 32.53 a	1011 ± 10.61 a	205 ± 21.92 c	1680 ± 21.21 b	668 ± 10.61 d	5.07 a	84.8 ± 0.07 c
Control	1324 ± 0.71 a	1263 ± 2.83 b	61 ± 2.12 a	1673 ± 11.31 ab	410 ± 8.49 b	6.17 ± 0.14 c	76.23 ± 0.53 ab

Mean±SD; different letters within a column indicate significant differences (p<0.05). BG, *Brea* gum; CMC; Carboxi Metil Cellulose; GG, *Gleditsia triacanthos* gum; XG, Xanthan Gum.

Table 3. Technological pasta quality of chickpea pasta as a function of hydrocolloid concentration

	Pasta with 1% of hydrocolloids		Pasta with 2% of hydrocolloids	
Sample	**Water absorption**	**Cooking looses**	**Water absorption**	**Cooking looses**
BGCP	1.98 ± 0.04 ab	12.35 ± 0.10 ab	2.07 ± 0.07 b	11.82 ± 0.37 ab
CMCCP	2.11 ± 0.10 b	11.97 ± 0.91 ab	2.38 ± 0.34 d	12.93 ± 0.11 bc
GGCP	2.00 ± 0.02 ab	12.31 ± 0.74 ab	2.20 ± 0.17 bc	10.83 ± 0.88 a
XGCP	2.02 ± 0.04 ab	10.99 ± 0.28 a	2.33 ± 0.11 cd	11.75 ± 0.36 ab
Control	1.89 ± 0.13 a	13.29 ± 0.30 b	1.89 ± 0.13 a	13.29 ± 0.30 c

Mean±SD; different letters within a column indicate significant differences (p<0.05). BGCP, Chickpea pasta made with *Brea* gum; CMCCP; Chickpea pasta made with Carboxi Metil Cellulose; GGCP, Chickpea pasta made with *Gleditsia triacanthos* gum; XGCP, Chickpea pasta made with Xanthan gum.

Table 4. Color profile of crude pasta

Sample	L*	a*	b*
BGCP	54.88 ± 2.19 a	9.17 ± 1.08 b	30.33 ± 2.34 b
CMCCP	55.94 ± 2.31 a	9.31 ± 0.58 b	31.23 ± 1.01 b
GGCP	53.75 ± 5.53 a	9.57 ± 0.79 b	29.13 ± 2.34 ab
XGCP	55.02 ± 4.61 a	9.70 ± 0.54 b	30.27 ± 1.49 b
Control	54.08 ± 3.6 a	8.15 ± 0.31 a	27.08 ± 4.24 a

Mean±SD; different letters within a column indicate significant differences ($p<0.05$). BGCP, Chickpea pasta made with *Brea* gum; CMCCP; Chickpea pasta made with Carboxi Metil Cellulose; GGCP, Chickpea pasta made with *Gleditsia triacanthos* gum; XGCP, Chickpea pasta made with Xanthan gum.

Table 5. Compression force necessary to fracture dry chickpea pasta

	Compression (N) as a function of concentration of hydrocolloids	
Sample	**1%**	**2%**
BGCP	1.01 ± 0.12 b	1.06 ± 0.04 b
CMCCP	1.20 ± 0.11 c	1.44 ± 0.09 c
GGCP	1.33 ± 0.30 c	1.32 ± 0.07 c
XGCP	1.52 ± 0.04 d	1.61 ± 0.04 d
Control	0.81 ± 0.11 a	0.81 ± 0.11 a

Mean±SD; different letters within a column indicate significant differences ($p<0.05$). BGCP, Chickpea pasta made with *Brea* gum; CMCCP; Chickpea pasta made with Carboxi Metil Cellulose; GGCP, Chickpea pasta made with *Gleditsia triacanthos* gum; XGCP, Chickpea pasta made with Xanthan gum.

Table 6. Firmness of cooked chickpea pasta during TPA analyses as a function of hydrocolloid concentration

Sample	Compression (N) as a function of concentration of hydrocolloids	
	1%	**2%**
BGCP	4.54 ± 0.16 bc	4.61 ± 0.17 b
CMCCP	4.25 ± 0.36 ab	4.62 ± 0.15 b
GGCP	6.17 ± 0.14 d	6.47 ± 0.07 c
XGCP	5.04 ± 0.23 c	6.22 ± 0.57 c
Control	3.72 ± 0.33 a	3.72 ± 0.33 a

Mean±SD; different letters within a column BGCP, Chickpea pasta made with *Brea* gum; CMCCP; Chickpea pasta made with Carboxi Metil Cellulose; GGCP, Chickpea pasta made with *Gleditsia triacanthos* gum; XGCP, Chickpea pasta made with Xanthan gum.

Table 7. Sensory attributes of chickpea pasta

Sample	Sensory attributes					
	Firmness	**Chewiness**	**Surface Stickness**	**Elasticity**	**Flavour**	**Order of preference**
XGCP	6.16 ± 2.03 a	5.96 ± 1.97 a	6.56 ± 2.27 a	5.08 ± 2.45 a	6.72 ± 1.46 a	2.04 ± 0.93 ab
BGCP	6.04 ± 1.99 a	5.96 ± 1.74 a	6.60 ± 2.00 a	5.08 ± 2.47 a	6.48 ± 1.78 a	2.24 ± 0.78 b
GGCP	6.20 ± 2.02 a	5.88 ± 2.07 a	6.76 ± 2.07 a	5.04 ± 2.37 a	6.24 ± 1.92 a	1.72 ± 0.68 a

Mean±SD; different letters within a column indicate significant differences ($p<0.05$). XGCP; Chickpea pasta made with Xanthan Gum, BGCP, Chickpea pasta made with *Brea* gum; GGCP, Chickpea pasta made with *Gleditsia triacanthos* gum.

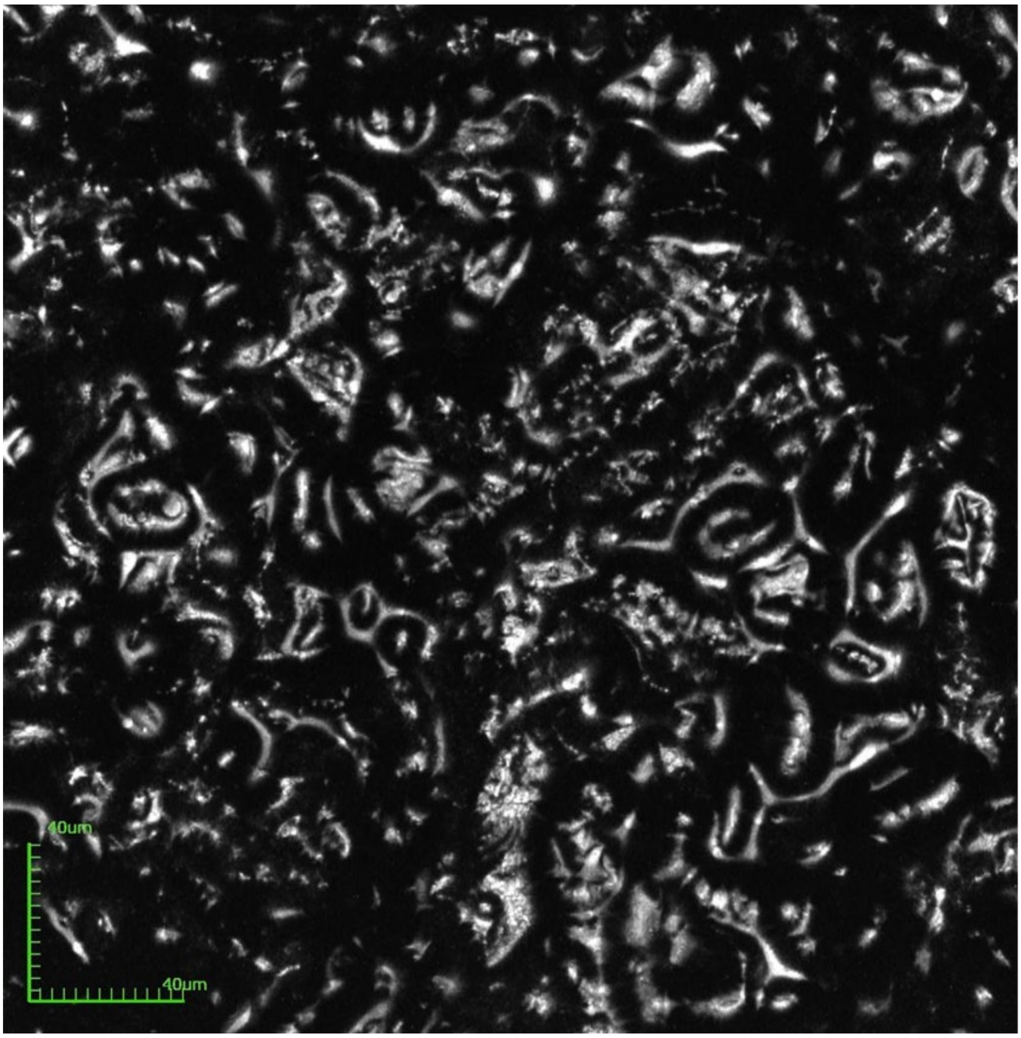

Figure 1. Confocal laser scanning microscopy image of crude chickpea pasta surface

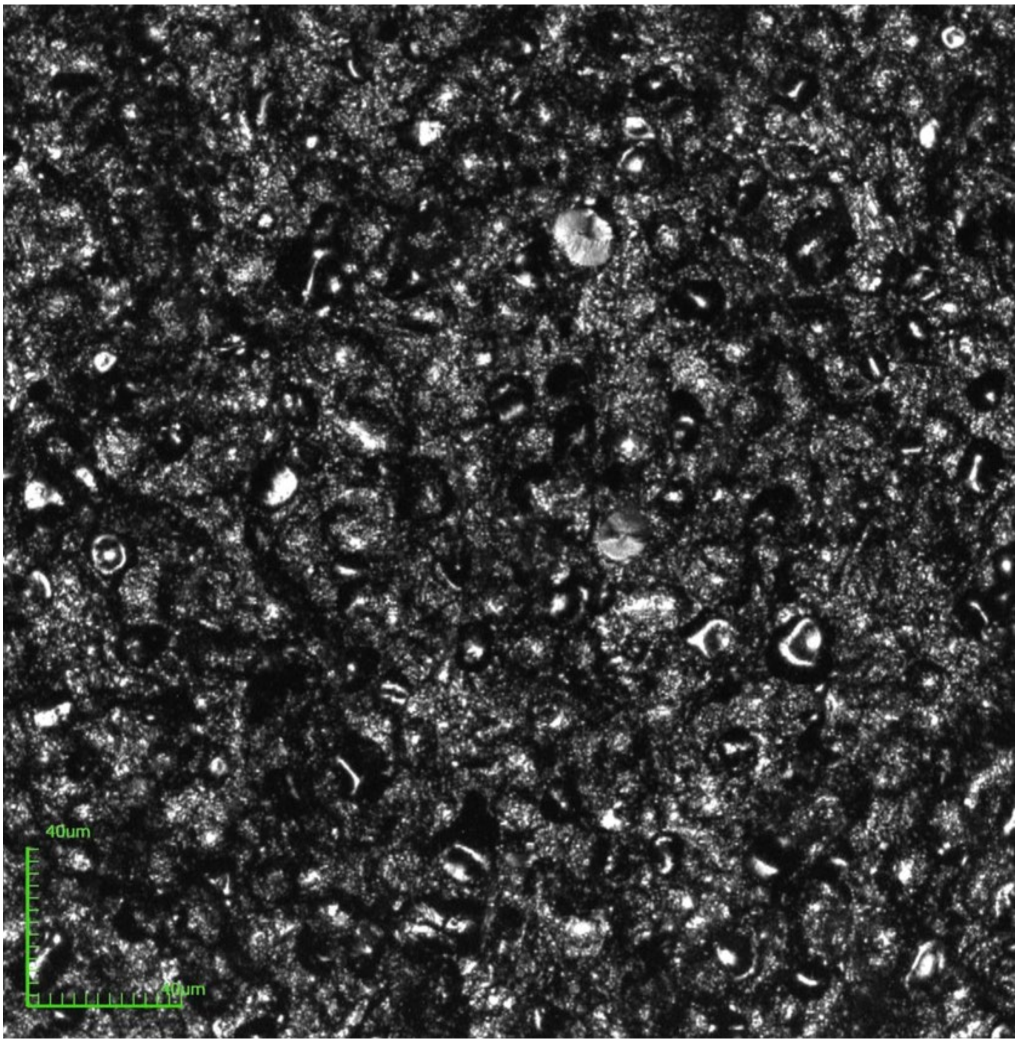

Figure 2. Confocal laser scanning microscopy image of cooked chickpea pasta surface