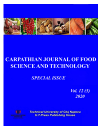

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EFFECT OF DIFFERENT TYPES AND CONCENTRATIONS OF HYDROCOLLOIDS ON PASTING, HYDRATION AND SURFACE ACTIVE PROPERTIES OF PIGEON PEA FLOUR

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ABSTRACT

Present investigation was intended to find the effect of different hydrocolloids on the functionality of pigeon pea flour. Different hydrocolloids viz. guar gum, xanthan gum, pectin, alginate and carrageenan were added in pigeon pea flour at 1%, 2 % and 3 % and their influence on the pasting, hydration and surface active properties was evaluated. Pasting temperature increased in case of guar gum, carrageenan and alginate and it was contrary in case of xanthan gum and pectin. Peak viscosity increased in case of guar gum and xanthan gum and decreased with the addition of pectin, alginate and carrageenan. Similar trend was observed for hold, final, breakdown and setback viscosity as well. Water absorption capacity increased and water solubility index decreased with the increase in the inclusion of hydrocolloids except for the gaur gum which showed contrary results. All hydrocolloids decreased the oil absorption capacity of pigeon pea flour. Swelling capacity of pigeon pea flour increased linearly with the addition of all hydrocolloids. Inclusion of hydrocolloids resulted in improving the foaming properties of the blends whereas no effect on emulsification capacity was observed with decrease in the emulsion stability.

1. Introduction

Hydrocolloids are important class of food additives that are widely utilized to confer good techno-functionality to the food products. Hydrocolloids, particularly gums have high molecular weight and miscibility in water (Şahin and Özdemir, 2007; Gomez et al, 2007) and thus results in conferring good mouth feel and viscosity owing to the good interaction of its polymeric chain (Bet et al., 2018). Thus, hydrocolloids owing to its viscoelastic nature can also be utilized for the formulation of various gluten free products where it tends to mimic the function of gluten to impart rheological characteristics to the food system (Rojas et al., 1999). In addition to altering the rheological properties to the food products, hydrocolloids also confer stability by minimising the retrogradation and thus providing good freeze thaw stability (Davidou et al., 1996).

Pigeon pea is an important legume having good nutritional profile and can be explored as an important source of protein for the fortification and formulation of various food products. Besides being an important source of protein, pigeon pea also contains substantial amount of starch which confers it functional properties owing to its pasting behaviour. Pasting properties of any flour is important for characterization of its starch for its commercial utilization due to the peculiar features it imparts to the food by virtue of its amylose and amylopectin content, utilization of various moisture and temperature regimes and interaction with other food constitutes and additives in the food systems (Torres et al., 2013). Gelatinization of starch involves a phase transition in which starch loses its crystallinity due to swelling by heating in excess of water with simultaneous leaching of amylose (Bet et al., 2018). However, the inclusion of hydrocolloids can result in interaction of hydrocolloids with the hydroxyl bonds of starch and change in its pasting properties (Fu et al., 2015). In addition to its affect on the pasting properties, hydrocolloids have tendency to interact with proteins and alter various functional properties like foaming and emulsification behaviour of the flour-hydrocolloid blend (Xie & Hettiarachchy, 1998; Mohammadian & Alavi, 2016).

The aim of this study was to determine the effect of different hydrocolloids on the functionality of the pigeon pea flour at different concentrations that are commonly employed in the food industry to confer good functionality to the various food systems. Functionality of the flour-hydrocolloid blend was studied by evaluating the effect of different hydrocolloids and their concentrations on the pasting characteristics, hydration properties, foaming and emulsification properties.

2. Materials and Methods

2.1. Materials

Pigeon pea was procured from local market of Ludhiana and grinded using Cemotech Mill (Model- 3303 Perten, Finland). Milled flour was sieved to obtain particle size of 40 µm. Food grade hydrocolloids viz. guar gum (GG), xanthan gum (XG), pectin (P), alginate (A) and carrageenan (C) were procured from Sisco Research Laboratories Pvt. Ltd, Mumbai, India.

2.2. Preparation of blends

Hydrocolloid-pigeon pea blends were prepared by inclusion of aforesaid hydrocolloids at 1, 2 and 3 %, followed by thorough mixing and sifting the blends from 40 µm twice to allow even mixing.

2.3. Pasting properties

Pasting properties of flour blends were studied usin

followed by heating upto 95 °C (heating rate 6 °C/min) for 7.5 min and holding at same temperature for 4.8 min and cooling down to 50 °C (cooling rate 6 °C/ min). Pasting parameters viz. pasting temperature, peak viscosity, hold viscosity, final viscosity, breakdown viscosity and setback viscosity were recorded.

2.4. Functional properties

Water absorption capacity and water solubility index was determined by the procedure followed by Anderson *et al.* (1969). Oil absorption capacity was determined by the procedure followed by Sosulski *et al.* (1976). Emulsification and foaming properties were determined by the procedure followed by Elkhalifa & Bernhardt (2010) and Khattab & Arntfield (2009) respectively.

2.5. Statistical analysis

Samples were analysed in triplicate using One-way analysis of variance and means were compared by post hoc Tukey HSD test. P-value< 0.05 was considered significant. The data obtained was analyzed statistically using SPSS software (Version 22.0, IBM Corporation, NY, USA) to determine statistical significance of the treatments.

3. Results and Discussion

3.1. Pasting properties

The pasting properties of pigeon pea flour and hydrocolloid system at different concentration of hydrocolloids are presented in Table 1. The pasting properties of pigeon flour are profoundly influenced by the addition of different hydrocolloids. Suspension of pigeon pea flour and hydrocolloid is a complex system of starch, protein and hydrocolloids that gels to form a paste. The pasting properties of the different pigeon pea flour and hydrocolloid systems are influenced by the interaction of different hydrocolloids with pigeon pea flour and this interaction is dictated by swelling characteristic of pigeon pea flour, morphological characteristic of hydrocolloid gel matrix and the resultant interaction between the starch and protein molecules of pigeon pea flour and gum matrix based on their thermodynamic compatibility depending on the molecular weight and heterogeneity (Biliaderis et al., 1997; Chaisawang & Suphantharika, 2006; Sikora et al., 2010).

Table 1. Effect of different hydrocolloids on pasting properties of pigeon pea flour

Hydrocolloid	Conc. (%)	Peak Viscosity (cp)	Hold Viscosity (cp)	Final Viscosity (cp)	Breakdown Viscosity (cp)	Setback Viscosity (cp)	Pasting Temp. (°C)
Guar Gum (GG)	0	764^{a}	718^{a}	986^{a}	46^{b}	268^{a}	90^{a}
	1	804^{b}	761^{b}	1073^{b}	43^{b}	313^{b}	90.7^{b}
	2	951^{c}	928^{c}	1328^{c}	23^{a}	400^{c}	91.5^{c}
	3	1058^{d}	1039^{d}	1491^{d}	19^{a}	452^{d}	91.6^{c}
Xanthan Gum (XG)	0	764^{a}	718^{a}	986^{a}	46^{a}	268^{b}	90^{d}
	1	1382^{b}	1127^{b}	1358^{b}	255^{b}	231^{a}	87.5^{c}
	2	2841^{d}	2090^{d}	2394^{d}	751^{c}	304^{d}	85.1^{b}
	3	2485^{c}	1653^{c}	1938^{c}	832^{d}	285^{c}	84.1^{a}
Pectin (P)	0	764^{d}	718^{d}	986^{d}	46^{a}	268^{b}	90^{b}
	1	697^{c}	610^{c}	754^{c}	87^{b}	144^{a}	90^{b}
	2	655^{b}	550^{b}	694^{b}	105^{c}	144^{a}	89.2^{a}
	3	599^{a}	472^{a}	611^{a}	87^{b}	139^{a}	89.3^{a}
Alginate (A)	0	764^{c}	718^{c}	986^{c}	46^{c}	268^{b}	90^{a}
	1	618^{b}	594^{b}	818^{b}	24^{b}	224^{a}	91.5^{b}
	2	529^{a}	523^{a}	745^{a}	6^{a}	222^{a}	-
	3	519^{a}	518^{a}	747^{a}	1^{a}	229^{a}	-
Carrageenan (C)	0	764^{c}	718^{c}	986^{c}	46^{a}	268^{b}	90^{a}
	1	643^{b}	599^{b}	803^{b}	44^{a}	204^{a}	91.1^{b}
	2	571^{a}	528^{a}	714^{a}	43^{a}	186^{a}	91.6^{c}
	3	566^{a}	521^{a}	721^{a}	45^{a}	200^{a}	92.2^{d}

Values are represented as mean (n=3). a,b,c,d The means within a line followed by different superscripts are significantly different at $p < 0.05$ by Tukey's test

3.1.1. Guar gum

Inclusions of guar gum resulted in increasing the pasting temperature, peak viscosity, hold viscosity, final and setback viscosity, whereas the breakdown viscosity of the starch paste decreased. The pasting temperature of flour reflects the ease of cooking of the starch which is directly correlated with the ease of ingress of water molecules in the starch granule for the gelatinization of starch. The inclusion of guar gum resulted in decreasing the available water for the gelatinization of starch due to competitive absorption of water molecules by guar gum (Khanna & Tester, 2006) and resulted in increasing the pasting temperature of pigeon pea-guar gum paste. Moreover, inclusion of guar gum can also dictates the degree of amylose leaching from the starch granules and further restricting the water availability (Christianson, 1882). However, the increase in the peak viscosity could be due to interaction between the leached out amylose and guar gum, whereas the increase in the final viscosity could be attributed to the interaction between the guar gum and amylopectin (Funami et al., 2005). Hold viscosity of the pigeon pea flour linearly increased with the increase in the concentration of the GG and thus suggests the improved stability of hot paste on cooking with the increase in the level of GG. Overall, the results suggest that inclusion of GG will result in improving the swelling and slightly increasing the cooking temperature. However, increase in gum concentration will result in increasing the propensity of pigeon pea-guar gum paste to retrogradation as depicted by higher values of setback viscosity. The susceptibility of pigeon pea-guar gum paste to increased retrogradation is due to thickening effect of the guar gum and increase in the concentration of low molecular weight amylose in the matrix (Funami et al., 2005a). Thus, pigeon pea-guar gum blends can be successfully employed for the formulation of noodles and pasta based products but less congenial for the formulation of the frozen products. Sikora et al. (2010) also reported increase in the brabender and setback viscosity for cereal and tuber starches with the inclusion of guar gum.

3.1.2. Xanthan gum

The inclusion of xanthan gum also increased peak, hot paste and final viscosities, however the linear increase was observed upto 2 % addition of xanthan gum unlike the incremental increase in these viscosities with inclusion of guar gum. This discrepancy can be attributed to the way the two gums behave at the molecular level; GG matrix tends to form entanglement solution whereas XG exhibits property of weak gel (Achayuthakan & Suphantharika, 2008). Paste containing XG exhibited high value of peak, hot paste and final viscosities by virtue of bridging flocculation where xanthan gum tend to adsorb on the surface of the starch granule and results in the synergistic interaction between swollen starch granules and XG (Sikora & Krystyjan, 2009). This interaction allows the proximity of starch granules by keeping them close and allows them to form better paste by easy ingress of the water that resulted in better swelling of starch granules (Mandala & Bayas, 2004). The effect of adsorption of xanthan gum on the starch granule can also be reflected on the incremental decrease in pasting temperature of pigeon pea-xanthan gum blends due to ease of ingress of the water molecule in the starch granule facilitated by the absorbed XG. However, the value of peak, hot paste and final viscosity decreased at 3 % concentration, which could be attributed to higher concentration of XG in the paste matrix that might resulted in poor paste formation due to poor interaction of starch molecules due to high electrostatic repulsion and poor gelation by competing with starch granules for water. No definite pattern for setback viscosity was observed with the increase in the concentration of XG. However, inclusion of 1 % XG exhibited lower value of setback in comparison of pigeon pea flour. The lower value for pigeon pea- xanthan gum blend paste can be attributed to reduced interaction of amylose chains among each other due to interaction between amylose and xanthan molecules (Leite et al., 2012). Therefore, the data suggests that inclusion of XG at 2 % in pigeon pea flour can confer better pasting properties to it and can be utilized for profoundly improving visco-elastic characteristic of the pigeon pea flour based dough. Also, the noodles and pasta based products formulated using pigeon pea- xanthan gum blend will have reduced cooking time with the higher inclusion of gum.

3.1.3. Pectin

Contrary to guar gum and xanthan gum, inclusion of pectin resulted in decreasing pasting temperature, peak, hot paste and final viscosities whereas the breakdown viscosity increased with the increase in the concentration of pectin. Propensity of pectin molecules to form hydrogen bonds with amylose molecules (Correa et al., 2013; Gałkowska et al., 2013) and covering the surface of starch granules (Ma et al., 2019) with resultant inhibition in the swelling of starch granules and subsequent leaching of amylose to thicken the paste resulted in low peak viscosity. Decrease in the hold viscosity and increase in the breakdown viscosity of pectin-pigeon pea blend can be ascribed to the destruction in the bonding of starch and amylose molecules due to shearing forces that resulted in easier deformation of the starch paste (Zheng et al., 2018). Similarly low value of setback viscosity can also be attributed to the bonding between pectin and amylose molecules that prevented the interaction of amylose chains with each other and decreased the retrogradation tendency of starch paste. Ma et al. (2019) observed decrease in the peak viscosity of corn starch paste with the inclusion of 0.5 and 1 % pectin, whereas Zheng et al. (2018) observed the similar progression of increase in the breakdown viscosity of lotus root starch and pectin blend. Above results suggests that pectin has positive influence on improving the freeze thaw stability of products by virtue of prevention of the tendency to retrograde and therefore can be utilized in the formulation of frozen food products from pectin-pigeon pea blend. However, it might not be congenial for the products which require the starch to form stable matrix during product processing and exhibit high pasting in noodle and pasta products. However, it can be efficiently utilized in the gruel based products.

3.1.4. Alginate

Similar pattern of decrease in the pasting temperature, peak, hot paste and final viscosities was observed with the addition of alginate. However, contrary to pectin decrease in the value of setback viscosity was observed with the addition of alginate. Increased hydration of alginate during pasting of starch rendered less water available for the starch to imbibe and swell and therefore resulted in increase in the pasting temperature (Li et al., 2017). Poor swelling of starch due to competitive water binding of alginate also resulted in reduced leaching of amylose from the starch granule due to its poor swelling and therefore resulted in decreasing the peak viscosity of the paste. Similarly, the decreased value of breakdown viscosity is attributed to poor swelling of the starch granules and the viscosity of the paste was only attributed to the hydrated alginate molecules which tend to endure the shear forces during the pasting cycle and resulted in low value of breakdown viscosity. The value of setback viscosity was decreased with the addition of alginate, however further increase in concentration after 1 % has not shown any significant change in the value of setback viscosity. Interaction of leached amylose and alginate are responsible for decreasing the retrogradation tendency of pigeon pea-alginate blend. Similar effect of increased pasting temperature and decreased value of setback viscosity was observed by Li et al. (2017) on normal corn starch. Zhao et al. (2015) also observed the increased peak temperature and decreased breakdown and setback viscosity with the addition of sodium alginate to wheat starch.

3.1.5. Carrageenan

Carrageenan on the other hand also exerted similar aforesaid effects on pasting temperature, peak, hot paste and final viscosities whereas no effect on the breakdown viscosity was observed. These effects could be attributed to the electrostatic interaction of proteins and carrageenan as well the entrapment of the carrageenan in the starch granules that resulted in change in the surface characteristics of starch granule and restricted its swelling and decreased the aforesaid pasting viscosities (McHugh, 1987; Huc et al., 2014).

3.2. Hydration properties

Hydration properties are important characteristics of flour for the formulation of food products and depict the functionality of the flour in the resultant food product. Hydrocolloids by the virtue of its affinity for binding water can profoundly improve the functionality of food system. Table 2 highlights the effect of different hydrocolloid concentrations on the hydration properties of pigeon pea- hydrocolloid blends. Water absorption capacity (WAC) of all the pigeon pea- hydrocolloid blends were found to be increasing with the increase in the concentration of the hydrocolloid except for the pigeon pea-GG blend that exhibited linear decrease in the WAC with the increase in the GG concentration. The WAC of pigeon pea flour is attributed to the presence of high amount of protein that imbibes the water and exhibits good hydration. However, presence of GG hinders the absorption of water by proteins present in pigeon pea flour. Moreover, the unexpected decrease in WAC due to addition of GG can be ascribed to rate of hydration of guar gum. Usually for practical applications, hydration rate of two hours is essential for proper imbibition (Mudgil et al., 2014). Therefore, decreased WAC is attributed to lower hydration time employed in evaluation of WAC.

Water solubility index decreased with the increase in the concentration of all hydrocolloids except for guar gum. Decreased WSI can be attributed to water imbibed by the hydrocolloids and increase in the viscosity of the blend that tends to trap the solids and prevent their leaching. However, slow hydration of GG resulted in lesser viscosity of blend and resulted in high WSI. As aforesaid, the WAC of pigeon pea flour is predominantly the function of proteins present in it whereas the swelling capacity of flour is predominant function of starch gelatinization. The incorporation of hydrocolloids resulted in the increase in the swelling capacity of pigeon pea flour by the virtue of gelation and resultant entrapment of water in the paste matrix. XG exhibited linear increase in the WAC whereas GG, A and C exhibited maximum SC at 1 % and pectin exhibited maximum SC at 2 %. Further increase in the concentration of hydrocolloids resulted in comparatively lower SC due to competitive water binding by hydrocolloids and decreased swelling of starch. Leaching loss is important property for the formulation of noodle and pasta products and low leaching loss is related to better product quality and behaviour during cooking. Incorporation of all the hydrocolloids except for alginate resulted in reducing the leaching loss. Reduced leaching loss is attributed to the better entrapment of solids in the viscous matrix of gelled starch-hydrocolloid matrix. XG and pectin exhibited linear decrease in the leaching loss with the increase in the concentration of hydrocolloid whereas GG and carrageenan exhibited minimum leaching loss at 2%. Incorporation of alginate exhibited increase in the leaching loss, however, the leaching loss showed no significant effect of hydrocolloid concentration after 1 %.

Table 2. Effect of different hydrocolloids on hydration properties of pigeon pea flour

Hydrocolloid	**Conc. (%)**	**Water Absorption Capacity (g/g)**	**Water Solubility Index (%)**	**Oil Absorption Capacity (g/g)**	**Swelling Capacity (g/g)**	**Leaching Loss (%)**
Guar Gum (GG)	0	1.178 ± 0.005^{d}	21.83 ± 0.12^{a}	1.142 ± 0.007^{c}	4.554 ± 0.009^{a}	35.18 ± 0.09^{c}
	1	1.115 ± 0.004^{c}	22.98 ± 0.17^{b}	1.128 ± 0.004^{b}	6.136 ± 0.012^{d}	34.23 ± 0.06^{b}
	2	1.061 ± 0.007^{b}	23.57 ± 0.09^{c}	1.088 ± 0.004^{a}	5.872 ± 0.009^{c}	33.86 ± 0.11^{a}
	3	0.988 ± 0.002^{a}	23.53 ± 0.03^{c}	1.085 ± 0.005^{a}	5.808 ± 0.011^{b}	35.84 ± 0.03^{d}
Xanthan Gum (XG)	0	1.178 ± 0.005^{a}	21.83 ± 0.12^{d}	1.142 ± 0.007^{d}	4.554 ± 0.009^{a}	35.18 ± 0.09^{d}
	1	1.594 ± 0.013^{b}	20.76 ± 0.10^{c}	1.115 ± 0.004^{b}	5.530 ± 0.012^{b}	33.08 ± 0.12^{c}
	2	2.065 ± 0.011^{c}	19.70 ± 0.00^{b}	1.088 ± 0.006^{a}	6.146 ± 0.011^{c}	32.83 ± 0.12^{b}
	3	2.617 ± 0.004^{d}	19.31 ± 0.00^{a}	1.122 ± 0.004^{b}	8.116 ± 0.013^{d}	31.42 ± 0.12^{a}
Pectin (P)	0	1.178 ± 0.005^{a}	21.83 ± 0.12^{d}	1.142 ± 0.007^{d}	4.554 ± 0.007^{a}	35.18 ± 0.09^{d}
	1	1.253 ± 0.010^{b}	19.68 ± 0.15^{c}	1.139 ± 0.011^{d}	5.496 ± 0.007^{b}	33.64 ± 0.04^{c}
	2	1.311 ± 0.011^{c}	19.23 ± 0.09^{b}	1.067 ± 0.005^{c}	5.878 ± 0.011^{d}	32.66 ± 0.07^{b}
	3	1.406 ± 0.005^{d}	18.88 ± 0.16^{a}	1.046 ± 0.005^{b}	5.764 ± 0.009^{c}	32.05 ± 0.11^{a}
Alginate (A)	0	1.178 ± 0.005^{a}	21.83 ± 0.12^{a}	1.142 ± 0.007^{d}	4.554 ± 0.007^{a}	35.18 ± 0.09^{a}
	1	1.185 ± 0.003^{b}	23.15 ± 0.12^{b}	1.095 ± 0.012^{a}	5.656 ± 0.023^{d}	36.25 ± 0.13^{b}
	2	1.199 ± 0.007^{c}	23.17 ± 0.09^{b}	1.111 ± 0.009^{b}	5.628 ± 0.014^{c}	36.07 ± 0.21^{b}
	3	1.227 ± 0.004^{d}	23.64 ± 0.02^{c}	1.211 ± 0.007^{c}	5.482 ± 0.012^{b}	36.13 ± 0.14^{b}
Carrageenan (C)	0	1.178 ± 0.005^{a}	21.83 ± 0.12^{b}	1.142 ± 0.007^{d}	4.554 ± 0.009^{a}	35.18 ± 0.09^{d}
	1	1.434 ± 0.004^{b}	20.93 ± 0.07^{a}	1.161 ± 0.004^{c}	6.136 ± 0.011^{d}	34.42 ± 0.07^{c}
	2	1.451 ± 0.012^{c}	20.83 ± 0.13^{a}	1.084 ± 0.006^{b}	5.872 ± 0.012^{c}	33.64 ± 0.11^{a}
	3	1.473 ± 0.015^{d}	20.87 ± 0.09^{a}	1.075 ± 0.004^{a}	5.808 ± 0.007^{b}	34.04 ± 0.09^{b}

3.3. Surface active properties

Data pertaining to the effect of different hydrocolloids on surface active (foaming and emulsification) properties is presented in Table 3. Foaming and emulsification properties of pigeon pea flour are attributed to its proteins. Foaming and emulsification properties of any flour are important for dictating its functionality in various processed food products where emulsification and foaming is vital for the formulation of food product. Food proteins are exposed to various processing conditions of temperature, pH, water activity, shear forces and various additives are added to it that alters the functionality of proteins during processing (Sahni et al., 2018). Therefore, hydrocolloids are added with proteins to improve their foaming properties and particularly to enhance the stability of foam (Mohammadian & Alavi, 2016). The value for foaming capacity and stability are 81.33 and 23.66 % and for emulsion capacity and stability are 61.76 and 60.29 % respectively. The values are higher than that reported by Oshodi and Ekperigin (1989). Higher protein solubility is prerequisite for the good foaming capacity and stability (Xie & Hettiarachchy, 1998). The enhancement in the foaming capacity was attributed to increased protein solubility and higher stability of the protein-hydrocolloid system can be ascribed to formation protein-polysaccaride complex by interaction with each other via interactions viz. electrostatic, H-bonding, hydrophobic and steric. (Kruif & Tuinier, 2001). Maximum foaming capacity and stability was observed at 3% for GG, P and A, whereas it was 1 % for C and foaming capacity remained same after 2 % in case of XG. Foaming capacity was found to be higher in case of anionic hydrocolloids in comparison to neutral GG. This could be justified on the basis of formation of soluble complex by protein- hydrocolloid interaction. Anionic hydrocolloids bind with cationic proteins and resulted in the formation of insoluble protein-hydrocolloid aggregates due to neutralization of charges (Schmitt et al., 1998) and further binding of anionic hydrocolloids to the neutral protein-hydrocolloid aggregates confers them negative charge and enhance their solubility (Ghosh & Bandyopadhyay, 2012). However, reduction in the foaming capacity after 1 % in case of carrageenan could be attributed to its highly anionic nature that might have resulted in electrostatic repulsion at higher concentration of gum.

Stability of food foams is dictated by the viscosity of interfacial liquid film that controls the rate of diffusion of entrapped air from the foam (Ghosh & Bandyopadhyay, 2012). Studies have reported that inclusion of hydrocolloids results in increasing the viscosity of solution with subsequent improvement in the foaming stability (Xie & Hettiarachchy, 1998; Mohammadian & Alavi, 2016). However, this increase in the viscosity of protein-hydrocolloid system is function of nature and structure of hydrocolloid (Xie & Hettiarachchy, 1998). GG, P and A exhibited highest foaming capacity at 3 % whereas XG and C exhibited highest foaming capacity at 1 %. Decrease in the foaming capacity after 1 % in case of XG and C can due to formation of excessively viscous solution and high electronegativity respectively that resulted in diffusion of air from the foams. Inclusion of hydrocolloids resulted in no effect on the emulsification capacity of the blend, however linear decrease in the emulsion stability was observed with the increase in the hydrocolloid concentration. Decreased stability could be attributed to thermal gelation of the hydrocolloids that resulted in diffusion of the oil entrapped in the emulsion.

Table 3. Effect of different hydrocolloids on surface active properties of pigeon pea flour

Hydrocolloid	**Conc. (%)**	**Foaming Capacity (%)**	**Foaming Stability (%)**	**Emulsification Capacity (%)**	**Emulsion Stability (%)**
Guar Gum (GG)	0	81.33 ± 0.57^{a}	23.66 ± 2.51^{a}	61.76 ± 0.00^{a}	60.29 ± 0.00^{b}
	1	87.66 ± 1.15^{b}	42.33 ± 2.08^{b}	60.78 ± 1.69^{a}	60.29 ± 0.00^{b}
	2	92.00 ± 0.00^{c}	70.33 ± 1.52^{c}	61.76 ± 0.00^{a}	59.80 ± 0.84^{b}
	3	99.33 ± 0.57^{d}	76.33 ± 1.15^{d}	62.74 ± 1.69^{a}	39.70 ± 0.55^{a}
Xanthan Gum (XG)	0	81.33 ± 0.57^{a}	23.66 ± 2.51^{a}	61.76 ± 0.00^{a}	60.29 ± 0.00^{c}
	1	86.00 ± 0.00^{b}	64.66 ± 2.08^{d}	61.76 ± 0.00^{a}	58.82 ± 0.00^{b}
	2	100.00 ± 1.73^{c}	58.33 ± 1.52^{c}	62.74 ± 1.69^{a}	58.82 ± 0.00^{b}
	3	97.33 ± 1.52^{c}	48.33 ± 2.51^{b}	61.76 ± 0.00^{a}	11.76 ± 1.89^{a}
Pectin (P)	0	81.33 ± 0.57^{a}	23.66 ± 2.51^{a}	61.76 ± 0.00^{a}	60.29 ± 0.00^{c}
	1	124.33 ± 1.15^{b}	114.33 ± 1.52^{b}	61.76 ± 0.00^{a}	60.29 ± 0.00^{c}
	2	125.66 ± 0.57^{b}	113.33 ± 2.51^{b}	61.76 ± 0.00^{a}	52.80 ± 1.67^{b}
	3	138.00 ± 0.00^{c}	124.00 ± 2.64^{c}	61.76 ± 0.00^{a}	44.26 ± 1.54^{a}
Alginate (A)	0	81.33 ± 0.57^{a}	23.66 ± 2.51^{a}	61.76 ± 0.00^{a}	60.29 ± 0.00^{b}
	1	105.00 ± 0.00^{b}	83.00 ± 2.00^{b}	60.78 ± 1.69^{a}	47.05 ± 0.54^{a}
	2	114.00 ± 0.00^{c}	88.33 ± 1.52^{c}	61.76 ± 0.00^{a}	47.45 ± 0.79^{a}
	3	120.66 ± 0.57^{d}	97.33 ± 1.15^{d}	61.76 ± 0.00^{a}	46.80 ± 1.13^{a}
Carrageenan (C)	0	81.33 ± 0.57^{b}	23.66 ± 2.51^{a}	61.76 ± 0.00^{a}	60.29 ± 0.00^{c}
	1	124.33 ± 0.57^{d}	102.66 ± 1.15^{d}	61.76 ± 0.00^{a}	50.58 ± 1.83^{b}
	2	107.66 ± 1.52^{c}	94.33 ± 1.52^{c}	61.76 ± 0.00^{a}	51.23 ± 1.63^{b}
	3	77.66 ± 0.57^{a}	60.66 ± 2.51^{b}	61.76 ± 0.00^{a}	38.34 ± 0.94^{a}

Values are represented as mean ± standard deviation. a,b,c,d The means within the line followed by different superscripts are significantly different at $p < 0.05$ by Tukey's test

4. Conclusions

Inclusion of different hydrocolloids altered the functionality of the pigeon pea flour. Pasting properties of different hydrocolloid-flour blends exhibited variations owing to the type of hydrocolloid added. Guar gum and xanthan gum were found to be potent hydrocolloids for improving the pasting properties of the pigeon pea flour and can be utilized for the formulation of pigeon pea flour based gluten free bakery, pasta and noodle products. Xanthan gum exhibited highest effect on the pasting properties and can be utilized even at low concentration of 1 %. However, it resulted in higher values for breakdown with the increase in the concentration of xanthan gum. Inclusion of pectin and alginate reduced the retrogradation tendency of paste and can be utilized in the formulation of frozen food products. However, these hydrocolloids are not congenial for the formulation of noodle and pasta products and can only be used in gruel based products. Hydrocolloids had positive influence on the water absorption and swelling capacity of flour, however incase of guar gum proper hydration time is required for exhibiting good functionality. Hydrocolloids decreased the OAC of pigeon pea flour and can be utilized for the low fat food formulations. Pigeon-pea hydrocolloid blends showed no synergism incase of emulsification capacity and decreased the emulsion stability. Therefore, hydrocolloid-pigeon pea combination is not suitable for the emulsion based products but can be used for improving the formulation of gluten free bakery and pasta products to development of healthy pigeon pea based formulations.

5.References

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