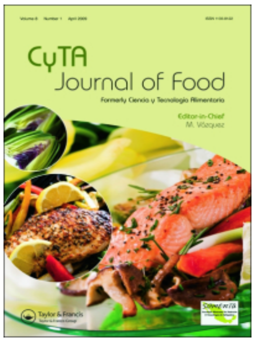

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Pasting properties of starch-okra pectin mixed system

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ABSTRACT

The pasting properties of starch are influenced by the starch-hydrocolloid interaction in the mixed system. In this study, the effect of pectin extract from three okra genotypes (*Agbagoma, Asontem*, and *Sengavi)* at concentrations of 0%, 5%, 10%, and 15% on the pasting properties of starch were investigated. The pasting properties of the mixed systems were determined using the Rapid Visco-Analyzer. The results showed that okra pectin decreased the peak viscosity and setback value of starch with the highest exhibited by *Agbagoma* and *Asontem*. The final viscosity of starch was increased in most samples except for 10–15% *Agbagoma* and 15% *Asontem* pectin systems. The peak time (3.84 – 6.84 min) increased with increasing okra pectin concentration. Pasting temperature for the mixed systems ranged from 51.24 °C (for 10% *Sengavi*) to 80.65°C (for 15% *Agbagoma*). Overall, okra pectin affected the pasting properties of starch and decreased starch retrogradation.

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Okra pectin; starch; polysaccharide; pasting properties; viscosity; retrogradation

PALABRAS CLAVE
Pectina de ocra; almidón; polisacárido; propiedades de pegado; viscosidad; retrogradación

Propiedades de pegado del sistema mixto de pectina de ocra-almidón

RESUMEN

Las propiedades de pegado del almidón son afectadas por la interacción de almidón-hidrocoloide en el sistema mixto. Este estudio se propuso investigar el efecto en las propiedades de pegado del almidón del extracto de pectina proveniente de tres genotipos de ocra (*Agbagoma, Asontem* y *Sengavi*), en concentraciones de 0, 5, 10 y 15%. Las propiedades de pegado de los sistemas mixtos se determinaron utilizando el Rapid Visco-Analyzer. Los resultados dan cuenta de que la pectina de ocra disminuyó la viscosidad máxima y el valor de retroceso del almidón, encontrándose que los valores más elevados corresponden a *Agbagoma* y *Asontem*. Se constató que en la mayoría de las muestras se incrementó la viscosidad final del almidón, excepto en los sistemas de pectina de 10 a 15% para *Agbagoma* y de 15% para *Asontem*. El tiempo de pico (3.84-6.84 min) aumentó con el incremento de la concentración de pectina de ocra. La temperatura de pegado de los sistemas mixtos osciló entre 51.24°C (para el 10% de *Sengavi*) y hasta 80.65°C (para el 15% de *Agbagoma*). En general, la pectina de ocra afectó las propiedades de pegado del almidón y disminuyó su retrogradación.

1. Introduction

Okra (*Abelmoschus esculentus*) is one of the most widely known and utilized species of the family Malvaceae (Naveed et al., 2009) and an economically important vegetable crop grown in tropical and sub-tropical parts of the world (András et al., 2005; Kpodo et al., 2017; Kumar et al., 2013; Nzikou et al., 2006; Ofori et al., 2020; Oyelade et al., 2003; Saifullah & Rabbani, 2009). Okra is a multipurpose crop due to the myriad uses of its fresh leaves, buds, flowers, pods, stem, and seeds (Agbenorhevi et al., 2020; Graham et al., 2017). The okra pods in the immature stage are consumed as vegetable and also used as thickening agent in soups and stews, largely due to the gelatinization effect of its carbohydrates. Soups and stews prepared with okra are usually consumed with bulky staple food (Agbenorhevi et al., 2020). It contains a complex carbohydrate or mucilage which has the ability to bind to serum cholesterol and thus reduce the risk of cardiovascular diseases and type 2 diabetes (Sengkhamparn et al., 2009).

The okra polysaccharide extract is predominantly pectin, consisting of galactose, arabinose, and galacturonic acid (Kpodo et al., 2017). The polysaccharides of okra have been isolated utilizing varied solvent strategies (Alamri et al., 2012; Alba et al., 2015; Archana et al., 2013; Georgiadis et al., 2011; Kpodo et al., 2017; Sengkhamparn et al., 2009). These polysaccharides, when extracted with an aqueous system results in a highly viscous solution with slimy appearance. This feature is often exploited when okra is added to soups to aid swallowing of dumplings such as *fufu, kokonte* and *banku (*Agbenorhevi et al., 2020). The polysaccharides are used as egg white substitute, gelling agent in jams and jellies, fat substitute in chocolate bars and frozen dairy desserts (Romanchick-Cerpovicz et al., 2002). In addition, okra polysaccharide has industrial applications and is used in confectionary (Datsomor et al., 2019), brightening agent in electro deposition of metals, deflocculant in paper and fabric production, combined with acrylamide to develop new biodegradable polymeric materials (Eze & Akubor, 2012).

Ghana produces tons of okra annually; however, okra still remains a minor crop and requires value addition to improve the economic gains and livelihood of growers. Starch is a complex carbohydrate that consists of amylose and amylopectin which are the determinants of physicochemical properties such as water-binding capacity, gelatinization

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temperature, swelling power, emulsifying stability, bulk density, and paste stability (Boudries et al., 2009; Slattery et al., 2000). During cooking, starch gelatinization occurs due to heat and shear action, however upon cooling, the disrupted amylose and amylopectin chains gradually reassociate into a different ordered structure in a process termed retrogradation (Wang et al., 2015). Starch retrogradation is usually accompanied by increased viscosity of pastes, gel formation, syneresis, and increased degree of crystallinity (Hoover et al., 2010).

Hydrocolloids such as guar gum, carrageenan, xanthan gum, flax seed gum, and gellan have been reported to have significant effect on the pasting properties of starch (Rosell et al., 2011). These non-starch polysaccharides inhibit retrogradation of amylose by forming complexes with the amylose chains which usually leach out during retrogradation. Macromolecular studies have shown that the pectin from okra is a potential new functional ingredient for useful application in food and pharmaceutical systems (Abe-Inge et al., 2020; Alba et al., 2015, 2013; Ghori et al., 2014; Kissiedu et al., 2020; Kpodo et al., 2017, 2018; Ofori et al., 2020; Tobil et al., 2020).

The objective of the present study was to evaluate the effect of different okra pectin concentrations on the pasting properties of starch.

2. Materials and methods

2.1. Materials

Okra pods (*Agbagoma, Asontem, and Sengavi* genotypes) were obtained from a farm in Ho, in the Volta Region of Ghana. Cassava starch was obtained from Kumasi Central Market in the Ashanti Region of Ghana. Okra pectin was isolated using the hot phosphate buffer extraction method at pH 6.0 as previously reported (Alba et al., 2015; Kpodo et al., 2017). The cassava starch used had amylose and amylopectin content of 20% and 80%, respectively (Williams et al., 2019). The *Agbagoma* pectin had 66.2% total carbohydrate, 5.4% protein, 20.9% Degree of methylation (DM), 31.7% Degree of Acetylation (DA), and Molecular weight (Mw) of 1419×10^3 g/mol. The *Asontem* pectin had 72.5% total carbohydrate, 3.8% protein, 20.4% DM, 40.1% DA, and Mw of 1233×10^3 g/mol. The *Sengavi* pectin had 66.2% total carbohydrate, 7.1% protein, 18.4% DM, 22.4% DA, and Mw of 1693×10^3 g/mol (Kpodo et al., 2017).

2.2. Preparation of starch-okra pectin mixed systems

A total sample weight of 4 g okra pectin-starch systems or blends were prepared by replacing 0%, 5%, 10%, and 15% of starch with pectin from each okra genotype (*Agbagoma, Asontem*, and *Sengavi*). The 0% pectin concentration (starch only) served as the control. The moisture contents of the starch and starch-okra pectin blends were determined.

2.3. Determination of pasting properties

The pasting properties of the starch-okra pectin mixed system were determined using the Rapid Visco-Analyzer Model 450 (RVA) (Alamri et al., 2012; Williams et al., 2019). To 4 g of control sample and okra-pectin-starch blends (14% moisture) were added 25 mL of distilled water and transferred into RVA canisters. The starch-pectin mixed system in the RVA was heated from 50°C to 95°C with 2 min holding time. The slurry was cooled at 2 min holding time. The peak viscosity, trough, breakdown, final viscosity, peak time, pasting temperature, and setback were analyzed using thermocline for Windows software.

2.4. Statistical analysis

All measurements were performed in duplicates. Data were subjected to analysis of variance and means were compared with Duncan Multiple range test using SPSS (version 20, IBM SPSS Statistics, US). Statistical differences were analyzed at 5% significance level ($p < .05$).

3. Results and discussion

Cassava starch (0% okra pectin control sample) exhibited higher peak viscosity than all the starch-okra pectin mixtures. All the concentrations of the starch-okra pectin systems studied decreased the peak viscosity of the starch in order of increasing concentrations of okra pectin except for the starch-*Sengavi* okra pectin mixed system, where samples with 10% okra pectin and 15% okra pectin had higher peak viscosity than that with 5% okra pectin (Tables 1, 2 and 3). The decrease in peak viscosity can be attributed to the limited granule swelling and reducing granule association theory, caused by coating of starch granules with okra pectin. This same observation was made by Alamri et al. (2012) where okra extract reduced the peak viscosity of rice and sorghum starches. Sanni et al. (2001) reported that peak viscosity is closely associated with the degree of starch damage and higher starch damage results in high peak viscosity. According to Etudaiye et al. (2009), flours with high peak viscosity demonstrates relatively weak associative forces between starch molecules. The water molecules are able to penetrate their starch granules much easier and the granular swell enormously leading to weakening of associated forces, which in turn makes them susceptible to breakdown resulting in weak gel systems. Comparing the

Table 1. Pasting properties of starch-okra (*Agbagoma*) pectin mixed system.

Tabla 1. Propiedades de pegado del sistema mixto de pectina de almidón-ocra (*Agbagoma*).

Pectin (%)	Peak viscosity (cP)	Trough viscosity (cP)	Breakdown value (cP)	Final viscosity (cP)	Setback value (cP)	Peak time (min)	Pasting temperature (°C)
0	2810.50 ± 67.18^a	1367.50 ± 20.51^a	1443.00 ± 46.67^a	1871.50 ± 64.35^a	504.00 ± 43.84^a	3.84 ± 0.05^a	76.75 ± 0.07^b
5	2615.00 ± 24.04^a	1560.00 ± 7.07^b	1055.00 ± 16.97^b	1896.50 ± 44.55^a	336.50 ± 51.62^b	4.17 ± 0.24^a	66.95 ± 15.98^{ab}
10	2006.50 ± 38.89^b	1471.00 ± 4.24^b	535.50 ± 43.13 ^{c}	1603.00 ± 46.67^b	132.00 ± 42.43 ^{c}	5.20 ± 0.00^{abc}	78.28 ± 0.04^b
15	1303.50 ± 96.87 ^{c}	1079.50 ± 43.13 ^{c}	224.00 ± 53.74^d	1158.50 ± 53.03 ^{c}	79.00 ± 9.90 ^{c}	6.34 ± 0.38 ^{c}	80.65 ± 2.19^b

[a–c]Values in the same column with different alphabets are significantly different ($p < 0.05$).

[a–c]Los valores en la misma columna con diferentes letras son significativamente diferentes ($p < 0.05$).

Table 2. Pasting properties of starch-okra (*Sengavi*) pectin mixed system.

Tabla 2. Propiedades de pegado del sistema mixto de pectina de almidón-ocra (*Sengavi*).

Pectin (%)	Peak viscosity (cP)	Trough viscosity (cP)	Breakdown value (cP)	Final viscosity (cP)	Setback value (cP)	Peak time (min)	Pasting temperature (°C)
0	2810.50 ± 67.18^{a}	1367.50 ± 20.51^{a}	1443.00 ± 46.67^{a}	1871.50 ± 64.35^{a}	504.00 ± 43.84^{a}	3.84 ± 0.05^{a}	76.75 ± 0.07^{b}
5	2176.00 ± 53.74^{c}	1631.00 ± 26.87^{b}	545.00 ± 26.87^{b}	2043.00 ± 41.01^{a}	412.00 ± 14.14^{a}	4.50 ± 0.90^{ab}	77.03 ± 0.60^{b}
10	2545.50 ± 115.26^{ab}	2173.50 ± 40.31^{c}	372.00 ± 74.95^{b}	2346.00 ± 59.40^{b}	172.50 ± 19.09^{b}	4.52 ± 0.45^{ab}	51.24 ± 1.54^{a}
15	2344.00 ± 9.90^{bc}	2024.50 ± 54.45^{c}	319.50 ± 64.35^{b}	2282.50 ± 9.19^{b}	258.00 ± 45.25^{b}	6.00 ± 0.38^{bc}	53.25 ± 2.83^{a}

$^{a–c}$Values in the same column with different alphabets are significantly different ($p < 0.05$).

$^{a–c}$Los valores en la misma columna con diferentes letras son significativamente diferentes ($p < 0.05$).

Table 3. Pasting properties of starch-okra (*Asontem*) pectin mixed system.

Tabla 3. Propiedades de pegado del sistema mixto de pectina de almidón-ocra (*Asontem*).

Pectin (%)	Peak viscosity (cP)	Trough viscosity (cP)	Breakdown value (cP)	Final viscosity (cP)	Setback value (cP)	Peak time (min)	Pasting temperature (°C)
0	2810.50 ± 67.18^{a}	1367.50 ± 20.51^{a}	1443.00 ± 46.67^{a}	1871.50 ± 64.35^{a}	504.00 ± 43.84^{a}	3.84 ± 0.05^{a}	76.75 ± 0.07^{b}
5	2591.50 ± 27.58^{b}	690.50 ± 40.31^{b}	901.00 ± 67.88^{b}	1918.50 ± 28.99^{a}	228.00 ± 11.31^{b}	4.42 ± 0.59^{ab}	76.98 ± 2.37^{b}
10	2582.00 ± 36.77^{b}	1821.50 ± 21.92^{c}	760.50 ± 14.85^{bc}	1989.50 ± 19.09^{a}	168.00 ± 2.83^{bc}	5.23 ± 0.14^{abc}	77.77 ± 2.03^{b}
15	2210.00 ± 56.57^{c}	1519.00 ± 9.90^{d}	691.00 ± 46.67^{c}	1599.00 ± 7.07^{b}	80.00 ± 2.83^{c}	6.25 ± 0.59^{c}	76.81 ± 4.37^{b}

$^{a–c}$Values in the same column with different alphabets are significantly different ($p < 0.05$).

$^{a–c}$Los valores en la misma columna con diferentes letras son significativamente diferentes ($p < 0.05$)

peak viscosities of the different concentrations of all three (3) okra pectin genotypes (Tables 1, 2 and 3), the starch mixed with 10% and 15% *Agbagoma* pectin exhibited lower peak viscosities, though the 5% pectin concentration was not significantly different from the control sample (Table 1). This implies that the *Agbagoma* okra pectin strengthened the associative forces between the starch molecules reducing the penetration of water molecules, hence limiting granular swelling and damage compared to *Asontem* and *Sengavi* okra pectin.

Trough viscosity also referred to as hot paste viscosity which measures the ability of starch to remain undisrupted when it is subjected to a long duration of high, constant temperature during processing (Jimoh et al., 2009; Williams et al., 2019) was significantly increased in the presence of most of the studied okra pectin varieties except for the mixture with 15% *Agbagoma* pectin (1079.50 cP) (Table 1) which had lesser trough viscosity than the 100% starch (1367.50 cP). The ability of a paste to withstand heating and shear stress is an important factor for most food processing operations. High paste stability is a requirement for industrial uses of starch because drastic changes in paste during and after processing could lead to textural changes that may be undesirable (Iwe & Agiriga, 2014). Incorporating okra pectin in starch food systems makes it a better raw material for the production of starch-based foods that require high hot paste stability.

Breakdown viscosity essentially measures the difference between peak and trough viscosities. The okra pectin from all varieties significantly affected the breakdown of the starch. Higher okra pectin concentration exhibited a decrease in breakdown value of the starch with 15% *Asontem* pectin recording the least breakdown value of 224.0 cP. According to Oduro et al. (2000), low breakdown value of starch suggests the starch granules are more stable during cooking and by extension a stronger cross-linking within the starch granules. This indicates that okra pectin influenced the cross-linking within the starch granules thereby making them less susceptible to breakdown (Farhat et al., 1999). Also, the low breakdown is associated with less starch granule rupture and can therefore guarantee a more stable cooked paste.

The effect of the different okra pectin on final viscosity was also explored. Final viscosity measures the stability of gelatinized starch and the ability of a starch to form a paste or gel after cooling (Shimelis et al., 2006). The current study revealed an increase in final viscosity in most starch-okra pectin mixed systems except for samples with 10% and 15% *Agbagoma* pectin and 15% *Asontem* pectin which demonstrated lower final viscosity than the 100% starch system. The decrease in final viscosity in the presence of okra pectin at varying concentrations had also been observed by Alamri et al. (2012) where okra extract at higher concentrations reduced the final viscosity of starch. Despite the varietal differences, the 5% starch-okra pectin mixture concentrations had no significant ($p > .05$) effect on the final viscosity of the 100% starch. The variation in the final viscosity can be attributed to simple kinetic effect of cooling on viscosity and the reassociation of starch molecules in the starch-okra pectin mixtures (Ikegwu et al., 2009). In the specific case of *Sengavi* pectin, the starch-pectin mixtures regardless of the concentrations generally exhibited highest final viscosities whiles starch-*Agbagoma* pectin mixtures exhibited least final viscosities. This indicates that food product developers can use pectin from *Sengavi* in food systems such as sauces, dressings, and soups whereas the latter can be incorporated in less viscous foods.

The setback value decreased significantly ($p < .05$) with increased pectin concentrations recording lower setback value. Similar observations had been made by Alamri et al. (2012) for rice and sorghum starches. However, the *Sengavi* sample with 15% okra pectin concentration had higher setback than the sample with 10% pectin concentration (Table 2). Setback is the cooling phase of the mixture during pasting in which a reassociation between the starch molecules occurs to a greater or lesser degree, and also a lower setback viscosity indicates higher resistance to retrogradation (Sanni et al., 2001). This implies that okra pectin like most hydrocolloids is suitable for retarding retrogradation; the cause of undesirable textural characteristics in starch-rich foods. The reduction of starch setback might be due to the competition of hydrocolloids (okra pectin) and amylose molecules to establish an intermolecular connection during cooling, thus decreasing the quantity of amylose–amylose interactions that are fundamental to starch retrogradation (Leite et al., 2012). Starch-pectin mixtures consisting of *Asontem* and *Agbagoma* pectin had higher setback reduction effect therefore could have wide food applications than starch-pectin composite from *Sengavi*.

The time required for cooking of starch containing products is termed peak time (Ekwu et al., 2011). In this study, the peak time ranged between 3.84 and 6.84 min (Tables 1, 2 and 3). The presence of okra pectin significantly ($p < 0.05$) increased the peak time with increasing concentrations of the different varieties of the okra pectin. The observed trend in this study is similar to that of Leite et al. (2012) where increasing concentrations of xanthan gum, carrageenan, sodium carboxymethyl cellulose increased the cooking time of cassava starch.

Pasting temperature indicates the least amount of energy required for the cooking of starch and also an indication of the onset of increase in viscosity (Shahzad et al., 2019). The least pasting temperature was recorded by 10% *Sengavi* pectin-starch blend (51.24°C) and the highest was recorded by 15% *Agbagoma* pectin-starch blend (80.65°C). The pasting temperature of the 0% concentration (100% cassava starch, 76.75°C) was not significantly ($p > 0.05$) increased by the presence of okra pectin concentrations except for 10% *Sengavi* pectin concentration (51.24°C) and 15% *Sengavi* pectin concentration (53.25°C). This implies that the inclusion of *Sengavi* okra pectin in cassava starch will reduce the cost of energy required for cooking. Contrary to the findings in this study, Leite et al. (2012) and Shahzad et al. (2019) observed a significant increase in pasting temperature of cassava starch and chickpea starch, respectively, with the inclusion of hydrocolloids.

The okra pectin genotypes differed significantly with respect to polymer effect on varied pasting properties of starch. This influence is attributable to differences in the viscosities of the individual okra pectin with *Sengavi* exhibiting the highest viscosity. Starch-*Sengavi* okra pectin mixed systems of different pectin concentrations demonstrated higher final viscosities.

4. Conclusion

The pasting properties of starch were significantly affected by the okra pectin, the extent of which depended on the okra genotypes and concentration. The final viscosity of the starch was increased in the presence of okra pectin independent of the concentrations except for samples with 10% and 15% *Agbagoma*, and 15% *Asontem* okra pectin which decreased the final viscosity of the starch-pectin system. The peak viscosity and setback value of the starch were decreased when okra pectin concentrations were increased. Pectin from the *Agbagoma* genotype in almost all concentrations recorded the lowest peak viscosity. *Asontem* and *Agbagoma* pectin at 15% in the starch-okra pectin mixed system exhibited least setback values indicating high resistance to starch retrogradation.

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Disclosure statement

The authors declare no conflict of interest.

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