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Formulating fruit fillings. Freezing and baking stability of a tapioca starch–pectin mixture model

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A B S T R A C T

Fruit fillings are a little-studied product. Their design and formulation must take a number of factors which are inherent to their applications into account, including stability during heat treatments such as baking and freezing, during which their quality must remain intact. The present study investigated systems containing native tapioca starch (TS), low methoxyl pectin (P, at two concentrations: 0.3% and 0.6%) and calcium, compared with TS alone and with a modified waxy corn starch (C), normally used in the industry, as control. All the systems were prepared with and without the addition of fruit. A method to measure the instrumental texture of filled pastries was developed and applied to study the effect of the baking process on two types of bakery products. The rheological results indicated that in the mixed TS-P systems pectin had the dominant role. The presence of fruit caused a significant rise in the G′ and G″ module values for all the thickener system formulations, but the effect was greater with the mixtures that contained pectin. This would indicate that the addition of solids and/or the extra pectin contributed by the fruit led to greater structuring. During freezing, the pectin gave rise to a different gel structure to that of TS alone and acted as a retrogradation and syneresis inhibitor. The extent of this effect depended on the added pectin concentration. Pectin also imparts the stability at high temperatures and conferred similar viscoelastic behaviour to that of the modified starch control (C). The TS-pectin system also proved bake stable.

1. Introduction

Fruit fillings are a little-studied product and very few papers deal with this subject. Native starches are widely used in industry in order to impart viscosity, texture, and stability to food products. Their use gives a 'clean' label and it has been shown that consumers perceive them as being familiar ingredients and as healthier than their modified equivalents or other thickeners (Varela & Fiszman, 2013). However, native starches are of limited use in a number of food applications because the pastes and gels prepared with them tend to break down with prolonged heating or under high shear or acidic conditions. Moreover, they have a strong tendency to retrograde and undergo syneresis on cooling (Galkowska, Dlugosz, & Juszczak, 2013). Therefore, native starches are physically or chemically modified in order to improve their performance. Another strategy for improving their techno-functional properties is to add a gum or hydrocolloid, as reported by numerous authors (Alloncle, Lefebvre, Llamas, & Doublier, 1989; Biliaderis, 2009; Breuninger, Piyachomkwan, & Sriroth, 2009; Chaisawang & Suphantharika, 2006; Chantaro, Pongsawatmanit, & Nishinari, 2013; Pongsawatmanit, Temsiripong, & Suwonsichon, 2007; Sikora, Kowalski, & Tomasik, 2008). In particular, to maintain or improve desirable textural properties and the stability of native tapioca starch-based products during long storage periods, hydrocolloids have been added to control the viscosity of the continuous phase and the textural properties of the final products (Pongsawatmanit & Srijunthongsiri, 2008). In a previous paper, the authors proposed a new model system for fruit fillings (pH 3, 35% sugar) which contained native tapioca starch, low-methoxyl pectin and calcium ions and improved their viscoelastic and texture properties (Agudelo, Varela, Sanz, & Fiszman, 2014). Since fruit fillings need to be stable during all kind of technological process conditions, in that paper a comparison with a control starch (highly cross-linked waxy corn starch, hydroxypropylated and phosphated) was performed; modification by etherification provides stability against

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retrogradation during refrigeration/freezing and modification by cross-linking provides stability against acid, thermal and mechanical degradation (Singh, Kaur, & McCarthy, 2007).

Hydrocolloid addition may decrease or increase the gel-like character of starch pastes, depending on the starch type as well as on the gum type and concentration. The most common observation is the increase in both viscosity and elasticity, with more pronounced effects on viscosity. The addition of a hydrocolloid can also accelerate gelation and reduce retrogradation (Rosell, Yokoyama, & Shoemaker, 2011).

According to Mandala (2012), retrogradation takes place in two stages. The first phase (short-term retrogradation) begins as the paste cools and a structure of entanglements and/or junction zones is created between amylose molecules, resulting in an elastic gel. This phase may last up to 48 h. The second phase (long-term retrogradation) involves amylopectin changes. It is a much slower process that may take place over several weeks, depending on the storage temperature. Both G′ and G″ increase upon cooling and during short-term storage, indicating that the gels are becoming firmer. Funami et al. (2005b) studied the effect of adding guar gum on corn starch retrogradation and found that the interactions between guar and amylose (or an 'amylose-like' component) should be considered a factor inhibiting short-term retrogradation of starch, because the interactions may reduce the amount of the starch components that participate in gelation. They hypothesized that interactions between guar and leached amylopectin may be a main cause of increased viscosity in a starch/guar system, and are probably also responsible for the decrease in the amount of leached amylose.

Galkowska et al. (2013) studied how high-methoxyl pectin and sucrose affected the rheological and textural properties of chemically-modified potato starch–pectin–sucrose systems and found that starch–pectin–sucrose gels exhibited better structuring ability and higher textural parameter values than the gels developed with modified potato starch alone. This effect was greater in at higher concentrations of starch.

Two heating steps should be considered when fruit fillings are formulated: heating during the fruit filling preparation (an intermediate step in industrial manufacture) and oven heating during the baking of the pastries. Heating affects the quality of the native starch-based fruit fillings, due to gelatinization and degradation of the starch upon heating at low pH values. The viscosity of the native tapioca starch paste decreases after heating; this fact will affect fruit filling applications, leading to textural instability during storage (Biliaderis, 2009; Temsiripong, Pongsawatmanit, Ikedab, & Nishinarib, 2005). In fruit fillings in particular, Wei, Wang, and Wu (2001) studied the effect of adding guar gum, locust bean gum, carboxymethylellulose, xanthan gum or kappa-carrageenan on the flow properties of model fillings formulated with waxy corn starch and commercial fruit fillings and found that the apparent viscosity varied with the gum type and concentration and with the shear rate.

Another key step for fruit filling formulations is refrigeration/freezing during storage, before or after baking: starch pastes may undergo changes in the starch biopolymer molecules, namely chain aggregation and crystallization. Moreover, it is difficult to maintain refrigerated/frozen food products at a constant optimum low temperature, and undergoing repeated freeze–thaw cycles during the supply chain leads to syneresis and to changes in rheological properties (Pongsawatmanit & Srijunthongsiri, 2008).

The effect of heating and freeze-thaw treatments on the pasting properties of tapioca starch (TS) with and without xanthan gum (Xan) has been investigated using a rapid viscoanalyzer (RVA). The breakdown values of both the TS and the TS/Xan mixtures increased with heating but the mixtures with Xan were more viscous due to the contribution of the Xan in the continuous phase of the mixtures. In repeated freeze-thaw treatments of the pastes analysed with the RVA, the TS/Xan mixtures exhibited lower water separation compared with TS alone (Chantaro & Pongsawatmanit, 2010).

Table 1
Composition of the different model system and fruit filling formulations at pH3.

Sample code	Ingredient					
	TS %	Pectin (P) %	$CaCl_2$ %[a]	MWCS %	Fruit (F) %	Sugar %
C	0	0	0	6	0	35
F C	0	0	0	6	20	35
1TS	6	0	0	0	0	35
F TS	6	0	0	0	20	35
P 0.3	5.67	0.30	0.033	0	0	35
F P 0.3	5.67	0.30	0.033	0	20	35
P 0.6	5.33	0.60	0.067	0	0	35
F P 0.6	5.33	0.60	0.067	0	20	35

TS = Tapioca Starch, $CaCl_2$ = Calcium chloride, MWCS = Modified Waxy Corn Starch, C = Control, P 0.3 = Pectin at 0.3%, P 0.6 = Pectin at 0.6%.
[a] The calcium salt dosages correspond to 40 mg of calcium ion per g of pectin.

Very little information is available on the effect of adding fruit to starch/hydrocolloid-based systems. The results reported by some authors indicate that adding fruit pulp modifies the rheological properties of the final products and changes their texture, and that these effects depend on a number of factors: pH, quantity of fruit added, type of fruit, fruit puree particle size, solid (sugar) content, hydrocolloid type and concentration, and the interactions between these factors (Baiano, Mastromatteo, & Del Nobile, 2012; Basu & Shivhare, 2010; Carbonell, Costell, & Duran, 1990a; 1990b; Fiszman & Duran, 1992; Wei et al., 2001). In particular, in systems that contain pectin the calcium available in the fruit is an important factor (Young, Kappel, & Bladt, 2003).

The objectives of the present study were to investigate the effect of heating and freeze-thaw treatments on the rheological properties of model systems for preparing fruit fillings containing tapioca starch-low-methoxyl pectin-calcium blends (35% sugar, pH 3) compared with a control (modified waxy corn starch system normally used in the fruit filling industry). In addition, the effects on the texture of adding fruit and of baking were investigated in two bakery products (open and closed systems).

2. Materials and methods

2.1. Ingredients

The ingredients employed were native tapioca starch (TS) (moisture content 13.7%, Sucroal S.A., Colombia), citric acid and sodium citrate (Sucroal S.A., Colombia), highly cross-linked waxy corn starch, hydroxypropylated and phosphated (C) (moisture content 12.3%, it contains virtually no amylose, Polartex 6716, Cargill, Spain), non-amidated low methoxyl apple pectin (P) (33–37% esterified, moisture content 12%, pH of 1% dissolution 4.5 to 5, kindly provided by Cargill, Spain) Unipectine OB700, Cargill, España, anhydrous calcium chloride (Panreac, Spain) and white sugar (S) (Hacendado, Spain). Fruit purée (F) was obtained from canned peach halves in light syrup (°Brix 17.7 and pH 3.7, Hacendado, Spain); the final moisture content of the fruit purée was 80.5%. Frozen pastry dough and pre-baked tartlet cases were used for preparing bakery specialities (see Section 2.6).

2.2. Model system and fruit filling preparation

The samples were prepared in a food processor-cooker (Thermomix TM 31, Wuppertal, Germany) equipped with temperature