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Effect of thermally inhibited starches on the freezing and thermal stability of white sauces: Rheological and sensory properties

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A B S T R A C T

The suitability of two physically modified (thermally inhibited) starches as a “clean label” alternative was investigated in the preparation of white sauces. The rheological and sensory properties of white sauces prepared with the two physically modified starches, a chemically modified starch and a native starch were evaluated before and after a freeze/thaw cycle. The thermally inhibited starches have similar pasting properties to the chemically modified starch, characterized by the absence of a breakdown in viscosity. The mechanical spectra showed that the structure of sauces prepared with the two types of thermally inhibited starches and with the chemically modified starch were practically unchanged after thawing, denoting a good freeze/thaw stability. However, in sauces prepared with the native starch, a decrease in tanδ was observed (from 0.49 to 0.20). All of the sauces exhibited shear thinning behaviour and thixotropy. Ranking tests were used to evaluate the sensory differences among sauces prepared with the different starches and paired comparisons were used to study differences between fresh and frozen/thawed sauces. In general, the thermally inhibited starches provided sauces of a similar sensory quality to the chemically modified starch.

1. Introduction

Starch is the most widely used thickening and gelling agent in the food industry because of the wide variety of textures and mouthfeel sensations it provides. The functional properties of starch are developed during the gelatinization process (Thomas & Atwell, 1997). The starch gelatinization process occurs when starch granules are heated in an aqueous medium at a characteristic temperature (gelatinization temperature), which produces irreversible granule swelling up to many times their original size, and the leaching of amylose from the granules as they swell (Mitolo, 2006). As heating continues, additional amylose and amylopectin are released and granule birefringence disappears (Miles, Morris, Orford, & Ring, 1985). A maximum peak viscosity is reached over the temperature range of 65–95 °C. This increase in viscosity is a desired property and results from the physical force or friction between the highly swollen granules. However, the swollen, hydrated starch granules are very fragile and, as the starch slurry is held at temperatures of 92–95 °C, native starch granules begin to fragment and the viscosity breaks down. Shear or conditions of extreme pH also tend to disrupt and fragment the granules, so that the starch polymers dissociate and become solubilized, leading to a rapid breakdown in viscosity. After heating, the solubilized starch polymers and the remaining insoluble granular fragments have a tendency to re-associate (retrogradation phenomenon). As a consequence, native starches have many limitations, including a poor thermal and shearing stability, a tendency to retrograde during cooling or/and freezing, a poorer viscosity and texture and less shelf-stability, all of which significantly reduce the quality of the final product (Jacobson, Obanni, & BeMiller, 1997).

In order to improve their performance and quality properties, native starches are chemically modified. The modification of starch chemicals by crosslinking makes it possible to control the swelling of starch granules and inhibit breakdown. Because of this inhibition, crosslinked starches are also called inhibited starches. Crosslinking or inhibition results in covalently-bonded inter and intramolecular bridges between starch polymers that reinforce the granule structure. Crosslinking controls the granular swelling and produces a starch that can tolerate high temperature, high shear, and acidic conditions. Another very frequent starch chemical modification is stabilization, which introduces chemical blocking groups between

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starch polymers, which prevent retrogradation after cooling and confer freeze/thaw stability (Thomas & Atwell, 1997).

However, despite the great quality benefits associated with chemically modified starches, the increased tendency towards natural, clean –label food has motivated the use of native starches and of alternative ways to alleviate native starch limitations.

Another alternative means of improving native starch functionality without chemical modification is by inhibiting the starch using a thermal process. This modification is a physical process, so the obtained inhibited starch possesses the label of a native starch (Haghayegh & Schoenlechner, 2011). Basically, the process consists of two steps: firstly, the granular starch is dehydrated and, secondly, the dehydrated starch is heat-treated for long enough and at a sufficiently high temperature to inhibit the starch. This thermal inhibition is supposed to increase starch resistance to breakdown, producing a non-cohesive, or "short" texture paste, preventing the appearance of a runny or gummy texture. An additional advantage is that starch increases the flavour of the product to which it is added, so the need for flavour enhancers is reduced. Depending on the extent of the heat treatment, various levels of inhibition can be reached. Lightly inhibited starches possess higher viscosity and little breakdown, whereas highly inhibited starches possess lower viscosity and no breakdown.

A type of food in which starch plays an important functionality is sauce. In particular, white sauces are composed basically of starch or/and flour, milk, oil and fat. White sauces prepared with native starches have exhibited poorer sensory quality attributes and freeze/thaw stability than sauces prepared with crosslinked and substituted starches. The quality of the native starch white sauce was improved by the incorporation of hydrocolloids to the sauce formulation, in particular when using xanthan gum, which would prevent interaction between amylose chains and, therefore, reduce retrogradation, lessening the negative effects of the appearance of graininess or a lack of homogeneity (Arocas, Sanz, Salvador, Varela, & Fiszman, 2010).

The aim of the present study was to evaluate the suitability of employing thermally inhibited starches in a white sauce formulation. The pasting properties and the effect of thermal processing and a freeze/thaw cycle in the flow, viscoelastic and sensory properties were evaluated.

2. Materials and methods

2.1. Starches

Four different starches were employed, supplied by UNIVAR IBERIA SA and manufactured by INGREDION Incorporated National Starch and Food Innovation (Westchester, IL, USA): native waxy corn starch (NS), chemically crosslinked and substituted waxy corn starch (QMS) and two thermally-inhibited, non-pregelatinized granular waxy corn starches (TISa and TISb).

2.2. Preparation and frozen storage of the white sauces

The white sauce consisted of powdered skimmed milk (9.30 g/100 g) (Central Lechera Asturiana, Asturias, Spain), sunflower oil (2.55 g/100 g) (Coosol), starch (6.00 g/100 g), salt (0.23 g/100 g) and water (up to 100 g). All of the ingredients were placed into a cooking device (Thermomix TM 31, Wuppertal, Germany) and heated up to 90 °C (17 °C/min) at 200 rpm and kept at 90 °C at the same agitation speed for 6 min. The obtained sauces were placed in crystal containers, covered with a plastic film, and cooled down to 20 °C in an ice-water bath. In the case of the study of the freshly prepared white sauces, measurements were taken on the same day.

In order to study the effect of a freeze/thaw cycle, the white sauces were placed in plastic containers at 20 °C and were frozen at −18 °C for four days. After frozen storage, the sauces were thawed at room temperature until they reached 20 °C and measurements were taken on the same day.

2.3. Rheological behaviour

2.3.1. Pasting properties

The pasting properties were studied using a starch pasting cell (SPC) attached to a controlled stress rheometer (AR-G2, TA Instruments, Crawley, England). The SPC consists of an impeller and a cylindrical cup (3.6 cm wide and 6.4 cm high). The impeller is designed to closely fit the cylindrical cup containing the sample. The top of the mixing element shaft is gradually extended to provide a non-contact conical shape cover, which significantly prevents solvent evaporation. Heating is accomplished through electrical elements placed concentrically to the cup, and cooling is achieved through water recirculation carried out in a helical conduct in close proximity to the cup's outer walls. The cooling water flow is controlled through the cooling control unit, which is placed upstream of the cup.

Measurements were taken in the starches dispersed in water (6 g/100 g). 25 g of the corresponding sample was placed in the cylindrical cup of the SPC. The sample was first vigorously stirred (100 s^{-1}) for 10 s at 30 °C, and then the shear rate was switched to 30 s^{-1} until the end of the test. The samples were heated from 30 °C to 90 °C at 15 °C/min, and then the temperature was held at 90 °C for 5 min. Subsequently, the samples were cooled down to 30 °C at 15 °C/min, and held at 30 °C for 5 min. The viscosity data were recorded over time; data collecting was performed using the TA data analysis software, provided by the instrument's manufacturer.

From the viscosity versus time curves, the following parameters were obtained: pasting temperature (PT), considered as the temperature at which viscosity begins to rise; peak viscosity (PV), considered as the highest viscosity value reached during heating; hot paste viscosity (HPV), considered as the viscosity value at the end of the isothermal period at 90 °C; the cold paste viscosity (CPV), considered as the viscosity value at the end of the isothermal period at 30 °C; in addition, relative breakdown (PV-HPV)/PV and relative total setback (CPV-HPV)/CPV were calculated.

2.3.2. Viscoelastic properties

The viscoelastic properties of the white sauces were studied using a controlled stress rheometer (AR-G2, TA Instruments, Crawley, England). A 40 mm diameter plate–plate geometry with serrated surface and a gap of 1 mm was employed. Before measurements were taken, the samples remained between the plates for 10 min as equilibration time. The exposed edges of the samples were covered with a silicon oil to avoid sample drying during measurements.

In order to simulate the effect of heating on the structure of the white sauce, temperature sweeps were performed from 20 °C to 80 °C at a heating rate of 1.5 °C/min and a frequency of 1 Hz. The applied strain was selected to guarantee the existence of a linear viscoelastic response according to previous stress sweeps carried out at different moments of the temperature sweep: 20 °C and 80 °C (applied strain = 0.001–0.025 as a function of the sample). The temperature sweep was stopped at the corresponding temperatures, and after 10 min as temperature equilibration time, the stress sweep was performed. The mechanical spectra in the linear region (applied stress = 0.3–0.5 Pa as a function of the sample) from 10 to 0.01 Hz at 20 °C were also recorded in separate tests. The values of the storage modulus (G'), the loss modulus (G''), the complex modulus (G^*) and the loss tangent ($\tan \delta = G''/G'$) were recorded.