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Heat treatment and turbo extractor rotational speed effects on rheological and physico-chemical properties of varietal applesauce

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ABSTRACT

We studied the effect of variety, ripening and processing parameters on applesauce rheology. Four varieties at 3 ripening stages were processed into applesauce. Apples were diced, heated to 85 °C for hot break process (no heating for cold break), fed to a turbo extractor (400–1800 rpm) and hot-packed. Samples were analyzed for rheological and physico-chemical properties. Results were analyzed by ANOVA and Tukey's test ($p \leqslant 0.05$). Variety, ripening, heating and extractor speed, significantly affected sauce properties. Increasing speed produced thicker sauce. Ripening improved consistency for Crispin and Cortland cold break sauces. Hot break produced consistent quality sauce over time with 60–100% less syneresis, 4–10% higher pectin, 20–45% smaller mean particle diameter, and 30–70% higher distribution span than cold break; thus, it could overcome variations in consistency from variety and ripening. Consistency and free-liquid flow could be predicted as functions of particle size, pectin content and pectin degree of methoxylation (R^2 = 0.80, 0.93).

1. Introduction

An important quality attribute of applesauce is its consistency, which is dependent on chemical components and physical properties such as size and distribution of apple tissue particles. These components can be affected by many factors, including variety and ripening of the fruit and any operations involved in post-harvest handling, storage and processing (Mohr, 1989). Godfrey et al. (1995) found that blanching Idared and Rome apples in hot water at 59–71 °C before pulping to sauce led to thicker sauces and believed that the effect was caused by pectin methylesterase activity. Additionally, Schijvens et al. (1998) reported that longer cooking times in a screw cooker with steam injection for Golden Delicious apple slices resulted in increasing applesauce apparent viscosity, applesauce serum capillary viscosity and water insoluble solids, but decreasing applesauce mean particle size. At the pulping step, increasing finisher screen opening size resulted in larger mean particle size, leading to higher apparent viscosity and consistency index (Nogueira et al., 1985; Rao et al., 1986; Schijvens et al., 1998). However, increasing finisher speed (500–900 rpm) caused an increase in mean particle size (Nogueira et al., 1985) but no effect on consistency index (Rao et al., 1986) with the same apple varieties and similar firmness ranges. Therefore, the processing-induced changes in applesauce rheology were likely resulting from changes in chemical and physical properties and seem to be very specific to the processing parameters involved. Colin-Henrion et al. (2009) have studied processing effects on dietary fibers and cell wall polysaccharides in applesauce, yet without information on applesauce consistency and particle size distribution.

In addition to processing, the ripening stage and variety of the fruit may affect applesauce consistency. Variations in raw material composition affect industrial processing of fruits, as nowadays apples are processed all year long due to availability from cold storage (0–2 °C, 90–95% relative humidity (RH)) and controlled atmosphere (CA) storage (−1 to 4 °C, 1–3% O_2, 4% CO_2) (Hardenburg et al., 1986; USDA, 2012). The main changes in apple composition from storage include loss of neutral sugars, solubilization and depolymerization of cell wall polysaccharides due to the combined action of several cell-wall-degrading enzymes on pectic and cellulosic fractions (Billy et al., 2008; Goulao and Oliveira, 2008). The effect of these changes on applesauce processing is yet to be determined. Additionally, commercial applesauce processing methods have changed from hot break to cold break

Abbreviations: d_{43}, volume based mean particle diameter; AIR, alcohol insoluble residue; BIC, Bayesian information criterion; HAC, hierarchical ascendant classification; PCA, Principal Component Analysis; PDM, pectin degree of methoxylation; Span, particle size distribution span; TSP, total soluble pectin.

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processes with the utilization of turbo extractors that can pulp the whole fruit to sauce or puree at room temperature without any thermal pretreatment. Understanding the influence of both raw materials and processing conditions on sauce properties will help to improve product quality. Our goals were to study the impact of apple variety, ripeness, and key processing parameters (heat treatment and extractor rotational speed) on rheological properties of applesauce, following current industrial procedures, and to model the relationship between physical, chemical and rheological properties of applesauce.

2. Material and methods

2.1. Applesauce processing

Four apple varieties (*Malus domestica*) from the 2010 harvest, Crispin, Cortland, Jonagold, and Idared were used for the study. Apples were sourced from upstate New York farms and had been kept in controlled atmosphere (CA) storage for 6–8 months. Immediately after receiving the fruit at the New York State Agricultural Experimental Station (Geneva, NY), apples were placed in cold storage at 10 °C and 95% RH) to accelerate fruit ripening, and processed into applesauce at three different ripening times; 0 (beginning), 18 (middle) and 36 (matured) days of storage.

Prior to processing, apples were weighed and tested for firmness using a hand-held penetrometer model FT 327 (Wagner Instruments, Greenwich, CT). Applesauce processing is shown in Fig. 1. Apples (~15 kg) were diced (1.27 cm) by a Dicer Model No. C (Urschel Laboratories Inc., Valparaiso, IN). Apple dices were steam heated in a Vulcan Steam Oven (Model 3TE; Diagon Devices, Inc., Pullham, WA) to 85 °C for 16 min (representing hot break sauce), and pulped by a turbo extractor (Bertocchi CX5, Bertocchi SLR., Parma, Italy) fitted with a 3.2 mm opening screen at three extractor rotational speeds: 400 (low), 800 (medium) and 1300 (high) rpm. The cold break sauce was unheated and pulped by the Turbo extractor, at higher rotational speeds due to the firmness of uncooked dices, at 800 (low), 1300 (medium) and 1800 (high) rpm. Water was added (10% and 15% for hot and cold break sauces, respectively) to standardize the soluble solids, and a small amount of 10% ascorbic acid solution was added to prevent browning prior to pasteurization. Sauce was pasteurized (t = 6 min, T = 90 °C) in an agitated steam kettle (Groen MFG. Co., Chicago, IL), and hot-filled into 16 oz glass jars. Jars were immediately capped, turned upside down for cap sterilization, held hot for 3 min and quickly cooled in a water bath to room temperature.

2.2. Rheology measurements

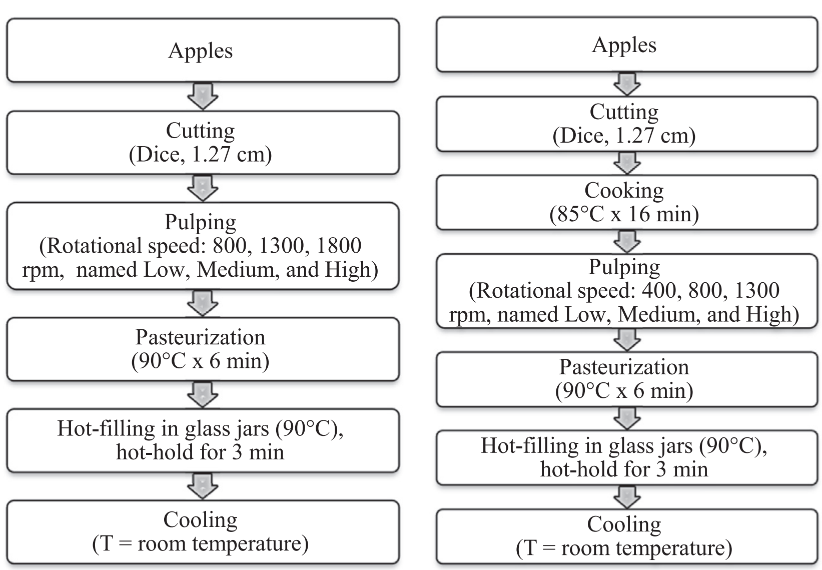
The measurements were carried out on a Brookfield DV-III Ultra programmable rheometer (Brookfield Engineering Laboratories, INC. Middleboro, MA) with V73 plus spindle to obtain values of shear stress for each applesauce sample. The measurements were determined by applying shear rate from 0.5 to 3.0 s^{-1} and then from 3.0 to 0.5 s^{-1} all at 25 °C. USDA applesauce consistency was measured according to the Grading Manual for Canned applesauce (USDA, 2005). USDA consistency sauce and liquid values were measured at room temperature by averaging the readings taken at the four quadrants of the USDA Consistometer flow sheet No.1, a plastic chart containing concentric circular markings 0.5 cm apart. The readings are taken at the edge of the spread of sauce and liquid separated from sauce after 1 min. USDA consistency free-liquid is obtained by subtracting sauce from liquid flow. Good quality sauce should have USDA consistency sauce value <6.5 cm and USDA consistency free liquid value <0.7 cm.

2.3. Particle size measurements

Particle size distribution measurements were performed using laser diffraction (Mastersizer model MS-2000, Malvern Instrument Inc., Westborough, MA). Applesauce samples were added into a water-continuous dilution accessory (2000 Hydro-S) filled with deionized water. The particle size distribution was calculated from the intensity profile of the scattered light. The volume based (d_{43}) mean particle diameter and the width of distribution (span) were obtained for every sample:

$$d_{43} = \sum n_i d_i^4 \Big/ \sum n_i d_i^3 \quad \text{where } n_i \text{ is the number of particles of diameter } d_i \tag{1}$$

$$\text{Distribution span} = (d_{90\text{th percentile}} - d_{10\text{th percentile}})/d_{50\text{th percentile}} \tag{2}$$



(a) Cold break process (b) Hot break process

Fig. 1. Flow chart of (a) cold and (b) hot break applesauce processing.