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Evaluation of Rheological Properties of Apple Mass Based Desserts

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***Abstract*—**The aim of the study was to evaluate the effect of texturizers on the rheological properties of the apple mass and desserts made from various raw materials. The apple varieties - 'Antonovka', 'Baltais Dzidrais', and 'Zarja Alatau' harvested in Latvia, were used for the experiment. The apples were processed in a blender unpeeled for obtaining a homogenous mass. The apple mass was analyzed fresh and after storage at –18ºC. Both fresh and thawed apple mass samples with added gelatin, xantan gum, and sodium carboxymethylcellulose were whisked obtaining dessert. Pectin, pH and soluble dry matter of the product were determined. Apparent viscosity was measured using a rotational viscometer DV–III Ultra. Pectin content in frozen apple mass decreased significantly ($p<0.05$) compared to the fresh sample. The viscosity of apple desserts immediately after their preparation depends on the physico-chemical properties of apples and the texturizers used in the production.

***Keywords*—**Apple variety, apparent viscosity, hydrocolloids, pectin, texturizers.

I. Introduction

FRUITS are considered as a commercially important and nutritionally essential food. Apples are fruits that contain the high pectin quantity, which is a dietary fiber, the entity "non-starch polysaccharide".

Freezing is used to preserve and maintain the quality of apple mass. One critical quality factor influenced by freezing is food texture. In some cases, the texture of the thawed material is close to that of the fresh and unfrozen food. In other cases, the texture may be changed by the freezing process and yet result in a thawed product that is still acceptable to consumers [1]. Texture can be defined as those properties of food determined by the rheological and structural nature of the food.

Food colloids open a lot of different possibilities in dessert production, which are used to perform certain functions [2]. The gelatin, xantan gum, and sodium carboxymethylcellulose are additives which are used as thickener, stabilizer, and dispersant in apple dessert. They impart high solution viscosity at low concentration and hydrate in most water-based systems because they are completely soluble. Xanthan gum and sodium carboxymethylcellulose are polysaccharides widely used for their unique ability to control the rheological properties of a wide range of food products. They dissolve readily in hot or cold product, provide uniform brine distribution, and are stable in acidic and alkaline solutions. It is important to observe that gelatin applications are not limited only to gelling properties. In fact, gelatins are also used as colloid stabilizer, foaming and surface absorbed agent and emulsifier [3].

For the dessert to obtain characteristic texture, fruit mass has to be whisked. Two factors have complex influence on the product to be processed: mechanical – whisking is carried out by mechanical mixing, and biological – gels derived as a result of swelling form the disperse medium. Both factors have equal technological importance, because by ignoring one of them the necessary final product is not obtained [4].

The aim of the study was to evaluate the effect of texturizers on the rheological properties of the apple mass and desserts made from various raw materials.

II. Materials and Methods

A. Raw Materials

The apple varieties - 'Antonovka', 'Baltais Dzidrais', and 'Zarja Alatau' harvested in Latvia State Institute of Fruit Growing, were used for the experiment. The variety 'Baltais Dzidrais' is one of the best early summer varieties, which ripens in the beginning or mid-August. The fruit flesh is white, juicy, and soft, of pleasant sweet-and-sour flavor. Storage period of fresh apples is only one month. The varieties 'Antonovka' and 'Zarja Alatau' are the late autumn-winter apple varieties, whose popularity can be explained by their resistance to cold winters and excellent storage feasibilities. Apples of the variety 'Antonovka' are big, green and upon ripening become yellow. Apples of the variety 'Zarja Alatau' are of variable size, beautiful yellowish color, firm flesh. 'Antonovka' can be stored at least for 3 months but the storage time of 'Zarja Alatau" is 6 months.

Apples were stored at temperature +3.0±0.5ºC and air humidity 80%. In order to measure indices of apples, they were processed in a blender unpeeled for obtaining a homogenous mass and placed into 200ml plastic vessels and quickly cooled to +4.0±0.5ºC. The prepared mass was used for dessert preparation immediately or thawed after frozen storage at –18ºC.

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B. Physico-Chemical Parameters

Photometric measurement was used to determine the composition of pectin. Pectin was isolated from the apple mass by leaching with ethanol, and from the residues – by extracting with diluted sodium hydroxide solution. By adding carbasol and sulfuric acid to the extract, through different intermediate stages carroty condensation product was formed, which was photometrically measured at 525nm [5].

For soluble dry matter measurement a digital refractometer ATAGO N20 (Japan) was used according to ISO 2173:2003.

pH was determined using a pH meter 3510 (Jenway, UK) according to the standard LVS EN 1132 - pH Determination of Fruit and Vegetable Juice.

C. Apple Dessert Preparation

Before apple dessert preparation, frozen apple mass was thawed for an hour at the room temperature. Both fresh and thawed apple mass samples were whisked at 1140rpm for 5min.

The gelatin (Latplanta, Latvia), xantan gum KELTROL (CP Kelco A. Huber Company, USA), and sodium carboxymethylcellulose CEKOL (CP Kelco A. Huber Company, USA) additives were used as thickener, stabilizer, and dispersant in apple dessert. They impart high solution viscosity at low concentration and hydrate in most water-based systems because they are completely soluble in both hot and cold mass. Before sample whisking the xantan gum (0.2% from sample mass) and sodium carboxymethylcellulose (0.2%) were added in powder form during whisking, while gelatin was swollen and dissolved in water – before sample was whisked. The apple mass sample with gelatin additive contains 3% of gelatin and 16% added water.

The samples of 100 grams of the product made from fresh apple mass or mass after frozen storage with three different additives were weighed into the 150ml glass beakers.

D. Apparent Viscosity Measurement

Apparent viscosity was measured using programmable rotational viscometer DV–III Ultra (Brookfield Engineering Laboratories, Inc., USA) at temperature of 20.0±0.3ºC. A T - bar spindle at 5rpm was used for viscosity measurement. In order to provide continuous contact of a spindle with the product, a Helipath Stand was used, which slowly raises and lowers the viscometer (at a rate of 7/8-inch per minute) during the measurement. Test parameters were set in software Rheocalc V2.6 as follows:

- SSN – *set viscometer speed* –5rpm;
- WTI – *wait for time interval* – 20s;
- DSP – *single data point*;
- LSC – *loop count* – 10.

Triplicate measurements of the apparent viscosity of apple desserts were done immediately after preparation and each hour during five hours. The means and standard deviations are presented.

E. Statistical Analysis

An analysis of variance (ANOVA) was conducted using Windows software SPSS (version 15.00). Significant differences between treatments were analyzed with the Tukey test at a significance level of $p<0.05$.

III. Results and Discussion

The apparent viscosity of apple mass based desserts was evaluated depending on the apple variety, type of raw material treatment, and additives used for the dessert preparation. The changes in apparent viscosity were observed within 5 hours after dessert production.

A. Physico-Chemical Parameters of Apple Mass

Research data indicate (Table I) that content of soluble solids may either increase (‘Antonovka’, ‘Zarja Alatau’) or decrease (‘Baltais Dzidrais’) after mass freezing depending on variety. There are more soluble solids in fresh apple mass of the variety ‘Baltais Dzidrais’ than in frozen ones. Whereas there are less soluble solids in fresh apple mass of the varieties ‘Antonovka’, ‘Zarja Alatau’ than in frozen apple mass. This can be explained by the fact that ‘Baltais Dzidrais’ is a summer variety, harvest and storage time of its apples is short.

TABLE I
DESCRIPTION OF THE APPLE MASS USED FOR DESSERT PREPARATION

Apple sample description		Soluble solids, Brix°	Pectin content, g 100 g^{-1}	pH
‘Baltais Dzidrais’	fresh	9.59±0.16	0.49±0.01	3.13±0.01
	frozen	7.15±0.14	0.31±0.01	3.24±0.05
‘Antonovka’	fresh	11.90±0.27	0.69±0.02	3.07±0.01
	frozen	13.10±0.50	0.61±0.02	3.18±0.01
‘Zarja Alatau’	fresh	13.77±0.08	0.82±0.02	3.25±0.02
	frozen	16.42±0.41	0.73±0.01	3.27±0.04

The autumn-winter varieties ‘Antonovka’ and ‘Zarja Alatau’ are harvested unripe (because of the climatic and storage considerations) and ripen in the wearhouse reaching good edible or consumption maturity.

The results of the research prove that pectin content has a close correlation with soluble dry matter ($r = 0.90$) and the equation of the regression line shows, that by increasing soluble dry matter content for 1 Brix°, pectin content increases by 0,054 g in 100 grams of the product (Fig. 1).

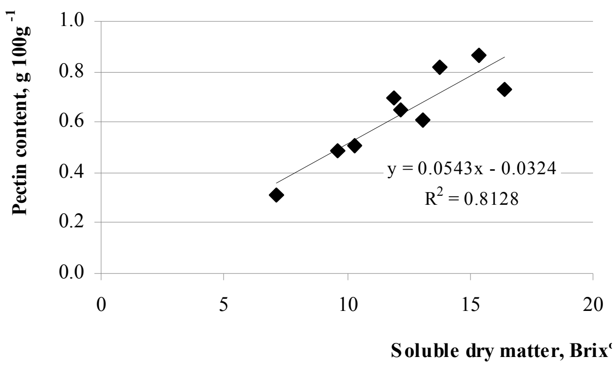

Fig. 1 Correlation of the pectin content with soluble dry matter

Results of the research indicate that the pectin content decreases significantly ($p<0.05$) as a result of apple mass freezing. The highest content of pectin was found in fresh apples of the variety 'Zarja Alatau'. It is established that pectin content is closely related to the ripeness stage of the apple. There are data available in the scientific literature, that total content of pectin substances in apples is 0.3–1.8%, pectin substances are encountered in the form of protopectin, pectin, and pectin acid. In green, unripe fruits, pectin is in the form of protopectin, which is of higher density and firmness than pectin. Both under the influence of ripening and heat treatment, protopectin transforms into pectin, fruit jelly forms [6]. Moreover, pectin acid forms in overripe fruits, therefore it should be provided, that fruit neither before harvesting nor during storage are overripe; products made from fruit containing less than 0.35% pectin substances, are not jellying.

The study of Boca et al. [7] prove that if it is assumed that pectin ability to gel in apples decreases at 0.35%, then apples of the variety 'Baltais Dzidrais' possess jellying power only one month after storage, and during freezing this ability decreases already just after freezing. Jellying power of the apple mass of the variety 'Antonovka' is maintained for 2 months after storage and freezing. The apples of the variety 'Zarja Alatau' have the most stable pectin quantity which jellying power is maintained for 3 months after storage in fresh and frozen condition.

The results of pH activity evaluation in fresh and frozen apple mass indicated no significant change ($p>0.05$).

B. Effect of Apple Variety and Type of Raw Materials

Fig. 2 shows that apparent viscosity of apple mass differed depending on the apple variety. Apparent viscosity was higher when the sample contained more soluble solids and pectic substances (see Table I). The medium close correlation ($r = 0.75$) was observed between pectin content and viscosity of apple mass.

Keenan et al. [8] reported that differences in textural properties of the purees may be attributed to individual characteristics of the apple cultivars i.e. dietary fiber content, level of structural tissue, moisture content and soluble solids. Dietary fiber content, as well as the proportion of soluble and insoluble fiber, could have an effect on the viscosity of a puree because of its ability to retain water within the matrix [9].

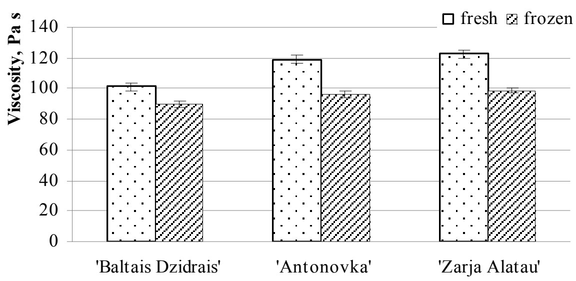

Fig. 2 Apple mass viscosity depending on the variety and type of raw material (fresh or frozen)

Since fruit mass is made up of serum (which is usually more Newtonian) and particles of various sizes and shapes dispersed within it, then the pulp with associated pectin may be the component contributing to non Newtonian behavior [10]. Moreover it has been reported that fruit mass behave as non-Newtonian fluid as a result of complex interactions among soluble sugars, pectic substances and suspended solids [11].

Freezing of product had a significant effect on the apple mass texture (Fig. 2). Apparent viscosity of apple mass decreased significantly ($p<0.001$) after freezing, probably due to water migration from cell fragments into aqueous solution (serum), as a result of change in osmotic pressure during freezing stage.

C. Effect of Additives

In the process of apple dessert production the decrease in apparent viscosity was observed compared to the initial raw material (Fig. 3). This behavior could be explained by the structural breakdown of the molecules due to the hydrodynamic forces generated and the increased alignment of the constituent molecules [12].

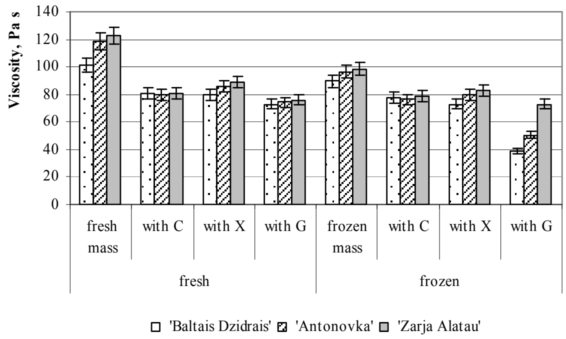

Fig. 3 Apparent viscosity of apple mass and desserts made with various additives: C – sodium carboxymethylcellulose, X – xantan gum, and G – gelatin

The viscosity of apple desserts immediately after their preparation depends on the apple variety and the texturizer used in the production. The lowest viscosity was observed for the desserts made from the variety 'Baltais Dzidrais' – summer apples with the lowest pectin and soluble solids content among studied samples. The desserts made from previously frozen apple mass with gelatin had lower viscosity than the samples made from fresh apples. Whereas the desserts made with sodium carboxymethylcellulose, and xantan gum had similar viscosity both when made from fresh or frozen raw materials. The desserts made with gelatin had lower viscosity immediately after sample production due to specific properties of this texturizer – it is used after dissolving in water and it has longer setting time.

Hydrophobic interactions are not responsible of chain aggregations in the cool dilute solution. Olivares et al. [13] reported that the gelation process, where for a concentration above a critical value (around 10^{-2} g cm^{-3}) a transition from sol to gel was observed at a given maturation time, when the maturation temperature is set below a gel temperature, above which gel is not achieved.

D. Effect of Thickening Time

The apparent viscosity of apple dessert immediately after addition of texturizer and whisking was significantly ($p<0.05$) lower than the one of apple mass used for dessert production.

On interaction between polysaccharide xanthan gum and other polymers, the hydrogen bonding and electrostatic interactions might occur [14]. During the first hours of apple dessert storage the viscosity of the samples increased (Fig. 4).

After one hour of thickening the viscosity of the apple mass (variety 'Antonovka') with gelatin increased for 8.1% and reached the viscosity of fresh apple mass (118.86±1.96 Pa·s). After three hours of storage the viscosity of the apple mass with added texturizer KELTROL reached the viscosity of fresh apple mass, but already after 5 hours it increased for 8.5% in comparison with fresh apple mass. In its turn, addition of the texturizer CEKOL influenced the viscosity of the apple mass the least. Its viscosity reached the viscosity of fresh apple mass only after the fifth hour of storage.

IV. Conclusion

Freezing of the product has a significant ($p<0.05$) effect on the apple mass soluble dry matter, pectin content, and viscosity. The viscosity of apple desserts immediately after their preparation depends on the physico-chemical properties of apples and the texturizer used in the product. The desserts with added carboxymethylcellulose, xantan gum, and gelatin had lower viscosity immediately after sample production than in apple mass before processing. During the first five hours of apple dessert storage the viscosity of the samples increased. The viscosity of fresh apple mass (variety 'Antonovka') was reached: with added gelatin during the first hour; with added KELTROL - after three hours; with added CEKOL - after five hours.

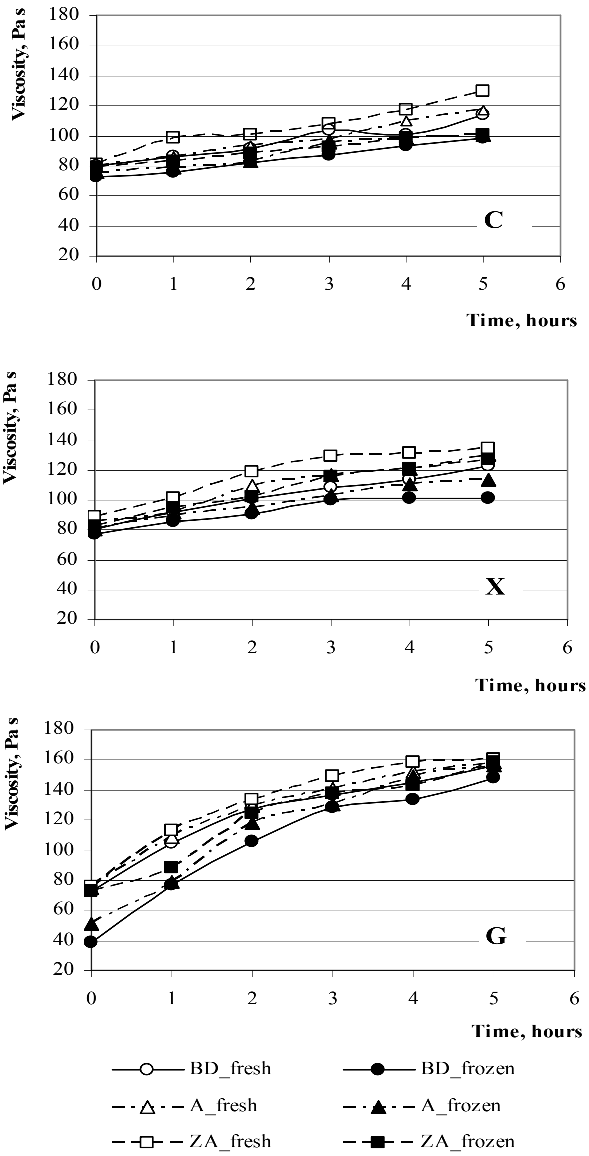

Fig. 4 Apparent viscosity of apple desserts made from fresh or frozen apple mass depending on texturizer used: C – sodium carboxymethylcellulose; X – xantan gum; G – gelatin

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