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Gel products properties influenced by freezing in different conditions

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ABSTRACT

The study objective was experimental analysis of gelatin gel freezing under differentiated, well-defined conditions to characterize the process kinetics. After thawing, the gel samples underwent the thawing drip analysis and their textural properties were evaluated. Freezing in liquid nitrogen ensures the highest freezing rate, whereas the least intensive procedure proves to be air freezing. There was stated unfavorable effect of the forced air freezing and in liquid nitrogen on thawing drip amount (water dilution, cracks of gel sample surface). The amount of thawing drip decreased with increasing gelatin mass fraction. The milk gel samples frozen in glycol (excluding 2% gelatin) showed no drip after thawing. The results of compression and penetration tests have given evidence of the influence of increasing gelatin share and gel freezing process on the gel texture characterized by maximal compression and penetration force.

Propriétés des gels selon l'influence de la congélation sous différentes conditions

Mots clés : Vitesse de congélation ; Azote liquide ; Gélatine ; Texture

1. Introduction

To satisfy market needs and increase foods sales, it is essential to provide good quality products, which is associated with in-depth knowledge of raw material functional properties. A choice and composition of materials determine the final product profile and quality, among others, its utility value, appearance, flavor, aroma and texture. These specific traits are developed while using the materials of thickening, stabilizing and gelling properties, known as hydrocolloids. Among commercial hydrocolloids used in the food industry, gelatin is regarded as special with a wide range of applications (Karim and Bhat, 2008, 2009; Phillips and Williams, 2009).

Gelatin is a protein product obtained from fibrous collagen by chemical-thermal methods. Collagen is the most abundant protein in mammals, makes up the bulk of the connective tissue and occurs widely in slaughter animal skin, bone, tendon, cartilage and fish (Haug et al., 2004; Montero et al., 2002; Rutkowski et al., 2003). Collagen is characterized by

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very complicated and highly developed protein structure. At the process of collagen converting into gelatine, the structure undergoes a partial reduction that causes changes in the specific chemical and physical properties of this natural protein (Rutkowski et al., 2003).

The functional properties of gelatin can be assigned into two groups. The first one includes the properties associated with gelling, e.g. gel strength, gelling time, melting temperatures, viscosity, thickening, texturizing and water binding. The second group relates to gelatin surface behavior, for example emulsion formation and stabilization, protective colloid function, foam formation and stabilization, film formation and adhesion/cohesion (Karim and Bhat, 2008; Surh et al., 2006).

In food industry gelatin is widely used as a thickener, especially a gelling agent in production of jellied meat, fish and culinary product as well as canned meat (at 1–10% ratio). Being a stabilizing and texture-forming component, it is used to bind meat juice and water, emulsification fat or obtain desired properties, like improved color stability or reduced cooking loss. Gelatin is also applied as sausage coating (so-called skinless sausage) forming a protective layer against drying and oxidation. The thickening properties of gelatin are used to produce food concentrates, sweets (jellies, desserts), besides it is applied as a texture stabilizer (e.g. whipped cream, ice cream, cake, bakery) and foam forming substance (Dłużewska et al., 2003; Imeson, 2010; Linden and Lorient, 1999; Phillips and Williams, 2009). It is also employed to help maintaining the right structure during the freezing-thawing process of cake or filling. Gelatin used in the dairy industry prevents the occurrence of syneresis or the solid particle sedimentation, e.g. fruit particles in yogurts (Pluta et al., 1999). It serves as texture stabilizer in low-fat products (Cheng et al., 2008; Yuet Hee et al., 2008). Due to its neutral flavor, it may be applied to enrich dietetic products with protein and act as an excellent nutrient carrier. Various technological and biopharmaceutical properties of gelatin facilitate formation of capsules, production of liquid drugs (e.g. vaccines), drops, granulated drugs and tablets as well as constitute material for blood plasma substitute production and haemostatic agents. Besides, gelatin coating of vitamins sensitive to light and oxygen increase their durability (Imeson, 2010; Linden and Lorient, 1999; Phillips and Williams, 2009; Rutkowski, 1999).

The research objective was to determine the effect of various freezing procedures on some chosen properties of gelatin-based gels. The studies included the preparation of research material, the gels, freezing processes under different conditions and characteristics of freezing process kinetics. Besides, the compression and penetration testing was used to study the textural properties of gels followed by the their sensory evaluation.

2. Material and methods

2.1. Material

The studies involved edible gelatin (*Gellwe*, *FoodCare*, *Zabierzów*), an animal-derived protein substance in the form of yellow granules of characteristic aroma. The model studies comprised gelatin gels prepared on the basis of tap water (pH 7.0), milk (*Mlekpol* pH 6.57) and orange juice (*Sokpol* pH 3.7) with the following gelatine mass share (2, 4, 6, 8, 10%) to solvent weight ratio. Preparation of colloid solution (sol) consisted in measuring out adequate amount of cold solvent (juice, water or milk) and addition of gelatin powder under vigorous agitation. Then gelatin granules swelled into discrete swollen particles that under the raising temperature up to 70 °C dissolved to form a solution. The prepared solutions were distributed into containers of 5.5 cm diameter and 32 cm^3 volume (for the penetration tests) and the containers of 5.5 cm diameter and 35 cm^3 volume (for the compression tests). The obtained solidified gel samples – not frozen (control) and those after the thermal treatment were studied.

2.2. Freezing and thawing

The gels were frozen using the following freezing techniques: air method (Freezer *Whirlpool*, Italy, natural convection conditions, temperature −33 °C) and immersion freezing (Immersion cryostat *Wiggen Hauser*, Germany, in glycol, temperature −35 °C) and liquid nitrogen immersion (Dewar *MVE Millennium, 2000*, USA – Cryopreservation System, temperature −196 °C). The freezing process continued until the temperature of −18 °C was obtained in the thermal centre of the prepared model. During the freezing, the sample thermal centre temperature was recorded by means of a multi channel digital thermometer equipped with thermoelements NiCrNi. The sampling frequency was 3 measurements per second, measurement accuracy ±0.05 K. All the measurements were preceded by the verification of the thermometer readings, taking the temperature of distilled water-ice bath. The recorded temperature changes in time were converted to the Excel balance spreadsheet to obtain the freezing curves which served for determination of the mean linear freezing rate according to the recommendations of the International Institute of Refrigeration (IIR, 2006).

$$\overline{w} = \frac{\delta}{\tau} \tag{1}$$

where $\overline{w}$ = mean linear freezing rate [cm h^{-1}], δ = thickness of frozen product [cm], τ = freezing time [h].

The samples after freezing were stored for 24 h in a cabinet freezer at temperature −33 °C. After 24 h, the samples were thawed at room temperature (+20 °C) until +10 °C was obtained in the centre of sample. Temperature in the sample center during thawing was measured with a multi channel digital thermometer equipped with thermoelements NiCrNi.

2.3. Evaluation of thawing drip loss

After thawing, the samples were dried with tissue paper and weighed each time to evaluate the amount of drip loss (L_D). The analysis of material weight changes caused by the drip loss was dependent on a freezing technique. Thawing drip loss was determined as a difference between the sample weight before and after the thawing process.

$$L_D = \frac{m_s - m_R}{m_s} \cdot 100\% \tag{2}$$

where m_s = material mass before freezing [kg], m_R = material mass after thawing [kg]