Journal of Food Engineering 144 (2015) 1–9

Contents lists available at ScienceDirect

Journal of Food Engineering

journal homepage: www.elsevier.com/locate/jfoodeng

Effects of maltodextrin on hygroscopicity and crispness of apple leathers

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ARTICLE INFO

Article history:
Received 8 April 2014
Received in revised form 11 July 2014
Accepted 13 July 2014
Available online 19 July 2014

Keywords:
Fruit leather
Crispness
Hygroscopicity
Maltodextrin
Snack

ABSTRACT

Fruit leathers are snacks made by drying a layer of fruit puree until a leathery consistency is achieved. Fruit leathers are mainly composed of low weight carbohydrates, which have low glass transition temperature (Tg) and are highly hygroscopic, so the product becomes sticky when stored at ambient relative humidity. In this work, apple leather strips (ALS) were prepared. Some formulations contained maltodextrin in order to decrease hygroscopicity. ALS hygroscopicity was evaluated by sorption studies, and crispness by mechanical and acoustic properties. Maltodextrin addition decreased the hygroscopicity of ALS. The addition of 15% maltodextrin reduced the moisture uptake by 45% to samples conditioned at 44%RH. At low moisture contents, the ALS become crispy. The crispness was lost as the moisture content of samples increase, following the modified Fermi equation behavior. The transition from crispy to soft material occurred at a water activity between 0.22 and 0.44. Addition of 15% maltodextrin increased the puncture force, puncture deformation and maximum amplitude up to 143%, 35% and 140% respectively. The variation of molecular weight and moisture content of snack products creates different texture and sensations at biting and chewing.

1. Introduction

Fruit leathers are restructured products widely consumed as tasty snacks in many parts of the world (Man and Sin, 1997; Vijayanand et al., 2000a,b; Babalola et al., 2004; Huang and Hsieh, 2005; Torleyet al., 2006). They are made by drying a thin layer of a fruit puree mixed with other ingredients until a pliable sheet is obtained, with a texture similar to a soft leather (Vijayanand et al., 2000a,b; Kaya and Maskan, 2003; Vatthanakul et al., 2010). The matrix of fruit leathers is comprised mainly of carbohydrates like sugars, pectins and cellulosic substances (Valenzuela and Aguilera, 2013) which have affinity for the surrounding water vapor, making the product highly hygroscopic (Mathlouthi and Roge, 2003; Tong et al., 2008). Sorption isotherm data reveal that fruit leathers stored at high RH may become very soft and microbiologically unsafe (Vijayanand et al., 2000a,b; Kaya and Kahyaoglu, 2005). As a result, hygroscopicity can be a problem during handling, packaging and storage (Phanindrakumar et al., 2005).

A possible solution for hygroscopicity is the addition of a carbohydrate polymer like maltodextrin (Telis and Martínez-Navarrete, 2009). Maltodextrins are a group of compounds derived from acid or enzymatic hydrolysis of starch (Chronakis, 1998; Wang and Wang, 2000; Dokic et al., 2004; Zheng et al., 2007) containing oligomers or/and polymers of α(1,4) D-glucose, with a dextrose equivalent (DE) less than 20 (Zheng et al., 2007). Maltodextrin improves the quality of dehydrated products, decreasing the stickiness and increasing product stability (Roos and Karel, 1991). This function has been attributed to the ability of maltodextrin to absorb water forming a moisture-protective barrier on the surface of hygroscopic particles, and to the capacity of increasing the glass transition temperature (Tg) (Chronakis, 1998; Avaltroni et al., 2004; Phanindrakumar et al., 2005; Gabas et al., 2007; Tong et al., 2008; Telis and Martínez-Navarrete, 2009).

Dry products with high Tg are largely characterized by their crispness or the pleasurable sensation of brittleness, fragility, and hardness when they are bitten, with a concomitant outburst of sound (Peleg, 2003). The assessment of crispness can be carried out by any mechanical method able to record the force when a deformation is applied to the product. Between these methods, the puncture test has been widely used because it simulates the mechanics of incisors at biting (Roudaut et al., 2002). A brittle fracture at low fracture force is characteristic of crispness. Also a series of subsequent fracture events can be distinguished, with an emission of sound associated to this fracture (Salvador et al., 2009). The intensity of the emitted sound depends strongly on the moisture content of the sample which is being testing (Tesch et al., 1996).

Loss of crispness is observed when the moisture content of low moisture products is increased (Suwonsichon and Peleg, 1998;

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http://dx.doi.org/10.1016/j.jfoodeng.2014.07.010
0260-8774/

Roudaut et al., 2002). The effect of hydration on crispness has been assessed by several authors (Roos et al., 1998; Suwonsichon and Peleg, 1998; Peleg, 2003). They argue that the change from a crispy to a deformable material is due to a glass transition of the product. Absorption of water molecules increases the free volume, which has an effect of plasticization that enhance the mobility and flexibility of molecules, making the product soggy with a soft texture (Roudaut et al., 1998, 2002). These changes result in a reduction of the glass transition temperature below the ambient temperature, so the rigidity of the material diminishes (Roudaut et al., 2002). At low moisture content, the partially plasticized material is able to sustain a higher strain, so the force to failure is high. In general, at high moisture contents the plasticization mechanism dominates and the hardness decreases resulting in a softer texture (Roudaut et al., 2002). However, in some materials, moisture sorption above certain level causes an antiplasticizing effect, where an increase of toughness as moisture content increases can be observed (Roudaut et al., 1998, 2002; Suwonsichon and Peleg, 1998).

To physically characterize hygroscopic solid food such as fruit leathers it is necessary to acquire knowledge regarding of both the water sorption and water plasticization properties (Roos, 1993). The main objective of this work is to study the effect of maltodextrin addition on the hygroscopicity of fruit leathers made from apple puree and assess their mechanical and acoustic properties as a function of water activity.

2. Materials and methods

2.1. Materials

Canned apple puree (Conservera Pentzke S.A., San Felipe, Chile) was purchased from a local supermarket. Total soluble solids of apple puree were measured with a digital refractometer (Atago, PR-201). Apple puree had 18 g soluble solids/100 g puree. Maltodextrin was provided by Hela (Hela Especias Chile S.A., Santiago, Chile). According to technical specifications provided by the manufacturer, the maltodextrin used had a dextrose equivalent (DE) of $17 \leqslant DE \leqslant 19$.

2.2. Moisture content

Moisture contents of apple puree and maltodextrin were determined by drying 5 g of sample in a convection oven at 105 °C until constant weight is achieved. The initial moisture content of apple puree was found to be about 4.52 ± 0.06 g water/g dry solids. The initial moisture content of maltodextrin was found to be about 0.01 ± 0.001 g water/g dry solids.

2.3. Formulation

Apple puree and maltodextrin formulation were designed to obtain final concentrations of 0, 5, 10 and 15 g maltodextrin/100 g mixture. At the end, all formulations had 18 g total solids/100 g mixture, considering the solids contained in the puree and the added maltodextrin. The moisture content of maltodextrin was so low that it was not considered in the formulation. The nomenclature for each formulation was set as 0%, 5%, 10% and 15% maltodextrin respectively (Table 1). The calculated amount of maltodextrin was first mixed with a small amount of puree (10% of total puree added in each formulation). This step was performed manually at 20 °C, taking care not to form bubbles, mixing using a glass rod until there were no lumps and the maltodextrin was uniformly dispersed, forming a homogeneous paste. The paste was then added to the rest of the puree.

Table 1
Materials quantities to prepare 100 g of mixture.

	0%	5%	10%	15%
Apple puree	100	95	90	85
Maltodextrin	0	0.9	1.8	2.7
Solids from apple puree	18	17.1	16.2	15.3
Total solids	18	18	18	18

2.4. Apple leather strips formation

The formulated apple puree was spread in a mold (2 cm × 7 cm; 0.02 cm high), and leveled using a glass rod to ensure the thickness of the puree was uniform. The molds were placed on an aluminum tray covered with a silicone sheet to prevent the apple leather strips (ALS) from sticking after drying. Drying was carried out in an air circulation oven (Memmert GmbH, Schwabach, Germany). ALS were dried at 70 °C to a final moisture content of approximately 0.11 g water/g dry solids. ALS were then transferred to desiccators and stored over P_2O_5 (%RH = 0.0) during 7 days to complete drying and allow equilibration of the moisture content within the ALS.

2.5. Thickness measurement of apple leather strips

ALS thickness was measured with Mitutoyo Absolute digital micrometer (Mitutoyo Corp, Kanogawa, Japan) at five random positions and average values were used in all calculations.

2.6. Moisture sorption measurement

The hygroscopic behavior and moisture isotherms of ALS were studied. ALS were equilibrated at different relative humidities (RH) at 20 ± 1 °C for about 20 days in desiccators according to the method described by Labuza et al. (1985). The desiccators contained the following saturated salt solutions: LiCl (RH = 11%), CH_3-COOK (RH = 22%), $MgCl_2$ (RH = 33%), K_2CO_3 (RH = 44%), $Mg(NO_3)_2$ (RH = 55%), $NaNO_2$ (RH = 65%) and NaCl (RH = 75%). To determine the hygroscopic behavior of ALS the samples weight were recorded at 0, 3, 6, 24, 48, 72, 96 and 120 h. For the construction of moisture isotherms the weight record was extended until there was no further variation in weight, point that is considered ALS reached the equilibrium. Equilibrium was reached within the time ALS samples were kept in desiccators.

2.7. Modeling the sorption behavior of apple leather strips

Experimental data were fitted to Oswin, Halsey and GAB equations (Table 2) to determine the best equation fitting the sorption behavior of ALS.

Regression analysis was performed using Microsoft Excel. Root mean squared error (RMSE) and coefficient of determination (r^2)

Table 2
Models used to fit the experimental sorption data of apple leather strips.

Name	Equation	
Oswin (Oswin, 1946)	$M = a\left(\frac{a_w}{(1-a_w)}\right)^b$	(1)
Halsey (Halsey, 1948)	$M = \left(\frac{-c}{\ln(a_w)}\right)^{\frac{1}{n}}$	(2)
GAB (Van den Berg, 1985)	$M = \frac{M_0 C K a_w}{(1-Ka_w)(1-Ka_w+CKa_w)}$	(3)

M: equilibrium moisture content (g water/g dry solids); a_w: water activity; a, b: Oswin's model constants; c, n: Halsey's model constants; M_0: monolayer moisture content (g water/g dry solids); C: Guggenheim constant; K: constant correcting the properties of the multilayer molecules with respect to the bulk liquid.