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Effects of different factors on stickiness of apple leathers

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ABSTRACT

Apple leathers (ALs) are restructured food products made by dehydration of a thin layer of apple puree, resulting in a thin and flexible sheet. AL are composed mainly by low-weight carbohydrates which are highly hygroscopic, so AL become sticky when stored at ambient relative humidity (RH). Stickiness in food could be considered as a negative or positive aspect. In this work, four factors affecting stickiness of AL were studied (ingredients, RH, surface rugosity and compression time), both to decrease and to increase it. Surface rugosity of AL had the greatest impact on stickiness, being the smoothest side stickier than the roughest side. The RH at which AL were conditioned and the ingredients used in this work also had a great influence on the adhesion force. In this manner, stickiness can be modified (increasing or decreasing) according to the specific requirements for using AL in different applications.

1. Introduction

Fruit leathers are products with an intermediate moisture content which have a flexible sheet form. They are consumed as snacks in many parts of the world (Torley et al., 2006). These products are light, pleasant to chew and tasty, becoming an attractive way to incorporate fruit to diet, especially for children and adolescents (Quintero Ruiz et al., 2012). The manufacturing process of fruit leathers consist on drying a thin layer of a fruit puree until a leathery consistence is achieved (Vatthanakul et al., 2010). Many kind of fruits can be used to make fruit leathers, like apple, papaya, mango, guava, durian, jackfruit, grape and kiwifruit, among others (Chan and Cavaletto, 1978; Irwandi et al., 1998; Vijayanand et al., 2000; Chen et al., 2001; Maskan et al., 2002; Gujral and Brar, 2003; Chowdhury et al., 2011; Quintero Ruiz et al., 2012). The fruit leather matrix (is composed mainly by) mainly consists of carbohydrates such as sugars, pectin and cellulosic substances (Torley et al., 2008). These hydrophilic compounds have affinity with the surrounding water vapor, making the matrix of these products highly hygroscopic (Mathlouthi and Roge, 2003; Tong et al., 2008). To prevent the fruit leather to absorb moisture from the environment after drying, the product must be packed properly and immediatly (Irwandi and Man, 1996; Man and Sin, 1997; Gujral and Khanna, 2002).

Stickiness (also termed pressure sensitive adhesion or tack) can be described as the adhesion force between two different materials which are in contact with each other under a light pressure (Hoseney and Smewing, 1999). Some food materials such as spray-dried fruit juices and fruit leathers tend to adhere to the processing equipments, packaging materials, fingers, palate and teeth (Kilcast and Roberts, 1998). This feature of the material to stick on surfaces is affected by the amount of sugars with a low molecular weight as glucose, fructose and sucrose (Adhikari et al., 2003). On the other hand, it has been documented that maltodextrins improve the quality of dehydrated products by decreasing their stickiness and increasing their product stability (Roos and Karel, 1991). This is because of the ability of maltodextrins to absorb water and create a surface barrier between particles, and to increase the glass transition temperature (T_g) (Telis and Martínez-Navarrete, 2009).

Stickiness can be considered both as a negative or a positive attribute. In food processing, stickiness slows the speed of the mechanized process and increases cleaning costs of equipments. The sticking of food to packaging results in product losses, packaging damage and product deformation. These parameters could have influence on the consumer acceptance, especially if they are finger food that stick to fingers while eating (Kilcast and Roberts, 1998; Hoseney and Smewing, 1999; Adhikari et al., 2003). Under other conditions, stickiness is desirable in products like toffees, sausages, and rice for *risotto* preparation (Michalski et al., 1997). Even more, stickiness is needed in the *lamination based technology.* This technique consists in assembling consecutive layers of a food base material fused with a bonding layer of the same or another material (Wegrzyn et al., 2012).

The most important factors affecting stickiness are viscosity, relative humidity, temperature, compression, food ingredients (especially low molecular weight sugars) and the kind of material

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that food is in contact with. For example, inorganic materials have a higher surface tension than organic materials (polymers). These polymers which present a low energy surface will absorb strongly to a high-energy surface in order to decrease the energy of the system (Kilcast and Roberts, 1998; Hoseney and Smewing, 1999). When at least one of these materials bonded together is flexible, the T-peel test has been often used to measure the adhesion strength (Watts et al., 1988; Song and Yu, 2002; Zumelzu and Gipoulou, 2002; Hadavinia et al., 2006). This test measures the force needed to pull apart two materials bonded in T form.

The objective of this study was to quantify the effects of ingredient type, the relative humidity, the surface rugosity and the compression time on stickiness in apple leathers. All these variables were measured in order to study their effect on the adhesion force, both to decrease and to increase it.

2. Materials and methods

2.1. Materials

Canned apple puree (Conservera Pentzke S.A., San Felipe. Chile) were purchased from a local supermarket. Total soluble solids of apple puree were measured with a digital refractometer (Atago. PR-201). Apple puree had 20 g soluble solids/100 g puree. Glucose and maltodextrin were provided by Hela (Hela Especias Chile S.A., Santiago. Chile). According to the label information, the dextrose equivalent (DE) of the maltodextrin was between 17 and 19. Low density polyethylene (LDPE) pouches were supplied by HOMS (Plásticos HOMS Ltda., Santiago, Chile).

2.2. Moisture content

The moisture content of apple puree and maltodextrin was determined by drying 5 g of sample (apple puree or maltodextrin) in a convection oven at 105 °C until constant weight was achieved. The initial moisture content of apple puree was found to be about 4.52 ± 0.16 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. Experiment division

As was stated before, stickiness can be considered as a negative or positive attribute. Regarding to the process conditions and packaging materials, the aim of this work was to determine which were the factor that reduce stickiness, to prevent apple leathers from adhere to the surface. Otherwise, when a sticky material is required for some specific applications such as lamination technology, the aim of this work was to determine which were the factors that increase stickiness of apple leathers. Therefore, the experiments were divided in two sections, studying stickiness decrease (I) or increase (II). In experiment I (decreasing stickiness), maltodextrin was used as an additive, since it has been found that it contributes to decrease stickiness. Also, the adhesion of apple leathers to packaging material (LDPE) was studied. In experiment II (increasing stickiness), glucose was used as an additive, since its low molecular weight contributes to increase stickiness. The adhesion of apple leathers to itself was also studied.

2.4. Formulation of apple leathers

For experiment I, apple puree and maltodextrin were weighted to obtain a final concentration of 0, 5 and 10 g maltodextrin/g total weight. For experiment II, apple puree and glucose were weighted to obtain a final concentration of 0, 5 and 10 g glucose/g total weight. The nomenclature for each formulation was set as 0%, 5% and 10% maltodextrin or glucose respectively. The calculated amount of maltodextrin or glucose 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 the ingredients using a glass rod until there were no lumps and the maltodextrin or glucose was uniformly dispersed, forming a homogeneous paste. The paste was then added to the rest of the puree.

2.5. Apple leather formation

Formulated apple puree was spread as a thin layer within the space of a 2-mm height frame placed in an aluminum tray. The puree was leveled using a glass rod to ensure the thickness of the puree was uniform. The aluminum tray was previously covered with a silicone sheet to prevent apple leather from sticking after drying. Drying was carried out in an air circulation oven (Köttermann 2736, Hänigsen, Germany). Apple leathers were dried at 60 ± 1 °C to a final moisture content of approximately 0.12 g water/g dry solids. 60 °C was determined as a suitable temperature to be used in the AL drying process due to it is high enough for a proper drying rate, and at the same time prevents the product to be burned (Valenzuela and Aguilera, 2013).

2.6. Thickness measurement of apple leathers and plastic material

Apple leathers and LDPE pouches thickness were measured with Mitutoyo Absolute digital micrometer (Mitutoyo Corp, Kanogawa, Japan) at six random positions and average values were used in all calculations. The thickness of LDPE pouches was 0.0855 ± 0.005 mm. The thickness of LDPE pouches was considered constant, while the thickness of apple leathers varied between samples.

2.7. Conditioning of apple leather strips

Apple leathers were cut into rectangular strips of 90 × 18 mm. These apple leather strips (ALS) were equilibrated at different relative humidity (RH) at 20 ± 1 °C for about 15 days in desiccators, according to the method described by Labuza et al. (1985). The desiccators contained the following saturated salt solutions: $MgCl_2$ (RH = 33%), K_2CO_3 (RH = 44%), and $Mg(NO_3)_2$ (RH = 55%). This humidity range (33–55%) was found to be the optimum conditions to maintain the rubbery-like state of the leather strips. At humidity levels greater than 55%, ALS were infested with mold, while the ALS became brittle below 33% humidity level (Valenzuela and Aguilera, 2015).

2.8. Scanning Electron Microscopy (SEM) surface analysis of apple leather strips

SEM was used to characterize qualitatively the ALS surface microstructure. Samples (at least 3 specimens per sample) were conditioned at 0% RH over P_2O_5, then sputter-coated with gold–palladium and examined with a scanning electron microscope (JEOL JSM 5300, Jeol Ltd., Tokyo, Japan), operated at an acceleration voltage of 20 kV. Images were taken within a specimen at different positions and magnifications. Selected images were reported. ADDA II was used as interface between the microscope and the computer and the images were analyzed with the software AnalySIS® version 3.2 (Soft Imaging System GmbH. Münster. Germany).

2.9. Compression of apple leathers strips

In experiment I, ALS were placed in contact with the LDPE packaging material. Both ALS and LDPE were previously cut into