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Diafiltration and agglomeration as methods to improve the properties of honey powder obtained by spray drying

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ABSTRACT

The aim of work was to find a method which will make possible to obtain honey powder of improved physical properties and/or reduced amount of carrier, comparing to traditional honey powder produced by a single-stage spray drying. Diafiltration (DF) was applied for partial separation of glucose and fructose from honey solution, that let to obtain honey powder with 75% honey content in dry basis. Moreover, honey powder produced from diafiltration retentate was characterized by better physical properties than obtained from non-DF treated honey. Agglomeration was applied to produce instant powders containing different amounts of spray dried honey. Additionally, the properties of powders during storage were investigated.

Industrial relevance: Drying of honey has great economical potential. However, honey powders obtained by spray drying usually have to contain not < 50% of carrier. Moreover, they have some drawbacks in their functional properties, such flowability, wettability and hygroscopicity making their packaging and utilization difficult. The possibility of enhancement the spray drying process of honey and physical properties of honey powders by diafiltration and agglomeration could be of high importance for honey producers and food industry.

1. Introduction

Honey powder is an attractive alternative for liquid honey. It is characterized by extended shelf life and it can be applied in the industry as a food additive, i.e. as an ingredient for cakes and other baked goods that enriches their attractiveness, improves flavour, color, aroma, texture and helps to maintain high product quality (Tong et al., 2010; Samborska, Langa, Kamińska-Dwórznicka, and Witrowa-Rajchert, 2015b); combined with retrograded starch could be used as a substitute for sucrose in baking bread (Sathivel et al., 2013); it can be also used in turkey breast meat before processing to enhance the oxidative stability (Antony et al., 2006).

The main components of honey are fructose (38–40%) and glucose (33–35%) with glass transition temperature T_g of 5 and 31 °C, respectively (Hebbar, Rastogi, & Subramanian, 2008; Shi, Fang, & Bhandari, 2013). Due to high content of fructose and glucose it is not possible to obtain honey powder without the addition of carriers characterized by high T_g. The form in which the material occurs during spray drying results from the relationship between product temperature and T_g (Noel et al., 1990). The amorphous material has to appear in a glassy form in order to obtain a free-flowing powder. It was explained before by Shi et al. (2013) and Samborska, Gajek and Kamińska-Dwórznicka, (2015a), while during last few years there were published some papers and patents dealing with this subject. Usually spray drying method is used for production of honey powder and different approaches are applied to enhance the drying process and powder properties. Nurhadi, Andoyo, Mahani, and R. (2012), Samborska and Bieńkowska (2013), Samborska and Czelejewska (2014) used different types of carriers (maltodextrin, dextrin, Arabic gum, whey protein concentrate) to perform spray drying of honey. Samborska, et al. (2015b) and Shi et al. (2013) used protein products (whey protein concentrate, sodium caseinate) as additional drying aids. Usually, the carrier content in honey powder cannot be lower than about 50% of solids to perform the drying properly and obtain powder with acceptable physical properties. Nurhadi et al. (2012) obtained honey powder by spray drying using carrier (maltodextrin and Arabic gum) to honey ratio 50:50, Samborska et al. (2015a) referred that using Arabic gum it was possible to obtain a product with a higher content of honey (67% d.b.) than in the case of maltodextrin (50% d.b.), but the powders obtained with gum Arabic were presented by worse physical properties: higher hygroscopicity and cohesion, and longer wetting time. Samborska, Śledź, and Witrowa-Rajchert (2015c) further proposed honey enzymatic pretreatment by glucose oxidase to reduce glucose content that let to obtain honey powder containing 83% of honey solids.

As low molecular sugars are the main obstacle in honey drying, diafiltration (DF) process could be potentially used for their partial separation from honey solution. DF is a technique that uses ultrafiltration membranes, and can be used to separate sugars, salts and acids from solutions containing proteins, pectin and other macromolecules (Yazdanshenas, Tabatabaeenezhad, Roostaazad, & Khoshfetrat, 2005). In DF process water is added to feed tank at the same rate as the permeate flux, making possible to elute low molecular ingredients, and reduce

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permeate decline with time (Goulas, Kapasakalidis, Sinclair, Rastall, & Grandison, 2002). A potential of DF to fractionate honey solution has not been critically evaluated yet. Although, membrane processing of honey was proposed by some researchers. Barhate, Subramanian, Nandini, and Hebbar (2003) proposed honey microfiltration (MF) and ultrafiltration (UF) as an alternative non-thermal method for honey treatment. MF and UF are used extensively in the food and pharmaceutical industries, for retaining particles, concentrating and purifying macromolecules (Maruyama et al., 2001). MF and UF belong to a group of membrane filtration processes that depend on transmembrane pressure as the driving force for separation. MF and UF membrane pore sizes span about four orders of magnitude, from approximately 0.001 μm for UF to about 10 μm for MF (Makardij, Chen, & Farid, 1999). The benefits of UF and MF unit operations applied by Barhate et al. (2003) to honey were: rejection of microorganisms and proteins, elimination of cloudiness or sedimentation/granulation, reduction of viscosity. However, sugar concentration did not change during MF and UF. In the current work the use of UF membrane (which is not a barrier for sugars, but in a diafiltration mode it is possible to elute them and to decrease concentration in feed) for honey treatment was proposed alternatively for the following reasons: the separation of glucose and fructose from honey solution, which could lead to: 1) the enhancement of subsequent spray drying process in terms of increased powder recovery, 2) the possibility to reduce the amount of carrier needed to perform drying, and 3) the improvement of powder properties.

Usually honey powders produced by single-stage spray drying have high bulk density, high hygroscopicity, poor wettability, medium or high cohesiveness and poor flowability, typical for powders with diameters <50 μm (Jinapong, Suphantharika, & Jamnong, 2008). The handling of hygroscopic and fine food powders is difficult. Typical problems connected with powders containing particles below 100 μm are: dusting, lumping, difficulty in dissolving in water, and inhibition of flow during dosage (Szulc & Lenart, 2012). Consumers, as well as food producers, desire a quick dissolution or dispersion of the powder in water without the formation of lumps. Manufacturers also require free flowing powders and absence of dust. All those requirements can be met by applying agglomeration - a size enlargement process, where small particles combine to form large relatively permanent masses, in which the original particles are still identifiable (Verdurmen et al., 2004). Agglomerated products are easy to use by the consumers and hence are preferred over the traditional not-agglomerated products, that are usually non-flowable (Dhanalakshmi, Ghosal, & Bhattacharya, 2011). In the current study new products based on honey dried powder, with a simultaneous improvement of its physical properties by subjecting it to the agglomeration, were produced.

The aim of work was to investigate the possibility to use: diafiltration as honey pretreatment (in order to enhance a subsequent spray drying, to reduce the amount of carrier added before spray drying and to enhance powder properties); agglomeration as powder final treatment improving its physical properties. Additionally, the changes of physical properties of honey powders during storage were investigated.

2. Materials and methods

2.1. Materials

Rape honey from local bee-keeper Krzemyk (Celestynów, Poland), Arabic gum (AG) from Hortimex (Warsaw, Poland), skim milk powder (1.25% fat) from OSM Koło (Koło, Poland), lecithin from Cargill Food Ingredients (Minneapolis, USA), were provided.

2.2. Diafiltration

3 kg of honey was diluted with 3 kg of distilled water. The ceramic tubular membrane (MWCO 15 kDa, diameter/length 25/585 mm, 23 canals, filtration surface 0,35 m^2) supplied by TAMI Industries (France) was operated using a laboratory installation 3XS29 (OBR Pleszew, Poland) in the batch/recirculating mode: feed solution was pumped to the membrane module, along the membrane and returned to the storage tank (Fig. 1). The permeate was collected continuously, upon receipt of portions of 100 mL of permeate the same amount of water (DF water) was added to the feed tank. At the same time intervals the following measurements were done: total time of the process, permeate flux J_p ($mL\ m^{-2}\ s^{-1}$), mass of the resulting 100 mL permeate portion and its extract content, transmembrane pressure, the temperature of material circulating in the system (maximum temperature was kept at 25 °C by cooling water in coil heat exchanger placed between the membrane and the feed tank). After receiving 2500 mL of permeate the process was stopped, the amount of permeate and retentate was measured. Feed solution (F), permeate (P) and retentate (R) were subjected to physico-chemical determinations.

2.3. Spray drying

30% aqueous solution of rape honey with AG (the amount of dry material derived from honey to derived from the carrier 50:50 - variant H/AG50) was spray dried in laboratory spray drier Lab 1 (Anhydro, Denmark) at inlet air temperature 180 °C, outlet air temperature 75 °C, atomizing disk speed 36,000 rpm (82,000 g), feed ratio speed 1 $mL\cdot s^{-1}$. DF retentate was supplemented with AG to obtain two levels of honey dry basis content to AG dry basis content ratio: 50:50 (variant R/AG50) and 75:25 (variant R/AG75), Spray drying was performed using the same parameters as for H/AG50. Partial powder recovery R_{P1} and total powder recovery R_P were determined as the ratio of the mass of solids collected after spray drying to the mass in the feed solution on a dry basis, directly after drying (R_{P1}), and after additional drying chamber cleaning to collect whole amount of powder (R_P). The whole amount of powder was used for further determinations and treatment.

2.4. Agglomeration

Two types of mixtures (powders) were agglomerated in a top-sprayed fluid bed granulator and dryer STREA 1 (Aeromatic-Fielder A.G, Bubendorf, Switzerland): 1) spray dried rape honey with skimmed milk powder 1:1 (honey dry basis - 25% of mixture - variant A25); 2) spray dried rape honey with skimmed milk powder 1:4 (honey dry basis - 10% of mixture - variant A10). 2% w/v aqueous solution of lecithin was used as a wetting liquid (binder solution). 200 g of powder was mixed for 1 min in fluidised bed by upward flowing air stream (inlet air temperature 50 °C), then the binder solution (20 mL) was fed by a peristaltic pump (flow rate 4 $mL\cdot min^{-1}$) to a two-fluid spray nozzle (air pressure on the nozzle 0,1 MPa), starting agglomeration process.

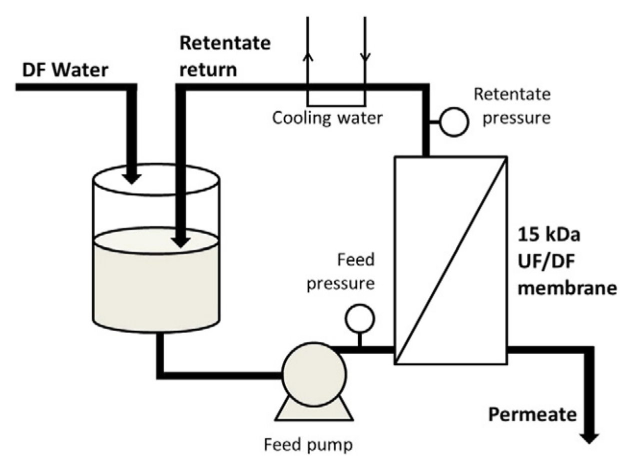

Fig. 1. Schematic diagram of diafiltration process.