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Effect of different fat replacers and drying methods on thermal behaviour, morphology and sensory attributes of reduced-fat coffee creamer

Simin Hedayatnia [a], Hamed Mirhosseini [a, *], Bahareh Tabatabaee Amid [a], Zaidul Islam Sarker [b], Sanja Kostadinović Veličkovska [c], Roselina Karim [a]

[a] Department of Food Technology, Faculty of Food Science and Technology, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[b] Faculty of Pharmacy, International Islamic University, Kuantan Campus, 25200 Kuantan, Pahang D/M, Malaysia
[c] Faculty of Agriculture, University "Goce Delčev", Krste Misirkov bb, 2000 Štip, Macedonia

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ABSTRACT

This study was conducted to investigate the effects of different fat replacers (i.e. inulin, 0, 2.5, 5 and 7.5% w/w; maltodextrin, 0, 15, 20 and 25% w/w) and agglomeration process on the characteristics of the reduced-fat coffee creamer. In the current work, the partial replacement of the hydrogenated fat with inulin and maltodextrin led to provide the reduced-fat creamer with desirable characteristics as compared to a commercial creamer. In this study, the creamer containing 25% maltodextrin and 7.5% inulin showed the highest glass transition temperature (T_g) and the lowest stickiness and moisture content among all formulated creamers. All instant-creamers from two-stage drying (spray drying followed by fluidized bed drying) had lower moisture content, bulk density, and stickiness as well as higher glass transition temperature (T_g) than the regular-creamer from the one-stage spray drying only. This might confirm the significant positive impact of fluidized bed drying on the physicochemical properties and functional characteristics of the reduced fat creamer. The sensory analysis revealed that the partial replacement of fat with 25% maltodextrin and 7.5% inulin resulted in the most acceptable instant coffee creamer comparable with the commercial product.

1. Introduction

Coffee is one of the most commonly consumed drinks in black or white form, depending on the preferred taste of the consumer. In general, a variety of milk and non-dairy products (creamers) are served for whitening purpose along with coffee (Kelly, Oldfield, & O'Kennedy, 1999). The majority of coffee drinkers prefer to add creamer and/or whitener to the dark coffee. However, most of coffee creamers and whiteners are considered as unhealthy products because they contain a high amount of saturated fats and/or hydrogenated oil. The coffee creamer is produced in the liquid and powder forms. The powdered creamer is more preferred than the liquid creamer because of its longer shelf life, more availability and easier transportation. This is mainly because it contains lower moisture content and water activity (a_w). In the technological point of view, the creamer powder should provide enough satisfaction in terms of instant properties, solubility, wettability, and dispersibility. It should dissolve rapidly without causing any coagulation or sedimentation in coffee (Kelly et al., 1999). The physicochemical properties of the creamer are mainly influenced by its composition and processing condition.

Spray drying technique is one of the most commonly applied techniques for manufacturing of creamer (Beeson & Erickson, 2001). Spray drying is the transformation of feed from a liquid or slurry form to the powder form (Maa, Nguyen, Sit, & Hsu, 1998). The formation of amorphous sticky particles on the dryer chamber's wall is one of the main technological issues occurred in spray drying (Chiou & Langrish, 2007). The surface stickiness of particles would increase during spray drying at 150–180 °C, thus leading to stickiness of the particles to drying chamber walls and lowering the yield of production (Sudhagar, 2000). Such particle stickiness leads to loss of materials, thus increasing the manufacturing cost because of frequent switching off the dryer for cleaning (Bhandari & Howes, 2005). On the other hand, spray-dried powders mainly have small

* Corresponding author.
E-mail address: hamedmi@upm.edu.my (H. Mirhosseini).

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particles (<50 mm) with poor handling and reconstitution properties (wettability, sinkability, dispersibility, and solubility); while it is more desired to have highly soluble powder, which does not form any lumps and aggregation after dissolving in water or milk. Such desired requirements can be achieved by applying agglomeration process (Turchiuli, Eloualia, El Mansouri, & Dumoulin, 2005). Agglomeration refers to the formation of permanent large aggregates by sticking particulate materials and particles (Kage, Nishihara, Ishimatsu, Ogura, & Matsuno, 2001).

In addition to agglomeration, the addition of proper and sufficient drying aid (such as skim milk powder and maltodextrin) to the premix formulation was recommended to overcome the stickiness and caking issues in powder products (Shrestha, Howes, Adhikari, & Bhandari, 2007). There are some cost- and technological limitations for using additives (e.g. fat replacers) in the powder products (Shrestha et al., 2007). Hence, the selection of a suitable fat replacer is highly encouraged to formulate a reduced-fat product with the desirable sensory attributes. Dietary fibers (such as inulin) are functional ingredients, which are commonly used in different food products (Elleuch et al., 2011). Inulin is known as a prebiotic, which cannot be digested by human digestive enzymes (Pharmaceutiques, 1995). It has also many beneficial effects on the human health (Gibson, Probert, Van Loo, Rastall, & Roberfroid, 2004). Inulin is classified to three groups based on the degree of polymerization (DP): native, short-chain and long-chain inulin (Glibowski & Bukowska, 2011).

Maltodextrin is also one of the most commonly used drying aids in the food industry. It is a carbohydrate composed of D-glucose units and dextrose equivalent (DE) of <20 (Uthumporn, Zaidul, & Karim, 2010). Maltodextrin can form the weak gel because of interactions between its helicoidal amylose and branched amylopectin molecules. Maltodextrin has been also used as a fat replacer, texture modifier and thickener. Maltodextrin plays a significant role in improving the glass transition temperature of the powder products, thus reducing the stickiness and caking issues. The characteristic of maltodextrin as a fat replacer is mainly because of its fat-like mouth-feel. This is presumably due to the formation of three-dimensional network especially when its gel has the irregularly shaped aggregates (3–5 mm in diameter). Such gel with the large aggregate has very similar structure to fat crystals, presumably contributing fatlike behaviour (Chronakis, 1998). As stated by Shrestha et al. (2007), maltodextrin can protect sensitive food components against unfavorable environmental conditions.

The main objective of the present study was to investigate the effects of type and content of fat replacer (i.e. inulin and maltodextrin) and agglomeration on the particle morphology, physicochemical properties and sensory evaluation of the regular-and-instant reduced fat creamers. In this study, different regular coffee creamers were produced by a one-stage spray drying; while all instant coffee creamers were produced by a double-stage drying (i.e. spray drying followed by fluidized-bed drying). Physicochemical properties of all formulated creamers were compared with the control and commercial creamers (Table 1). To the best of our knowledge, there is a lack of fundamental research on the stickiness and other characteristics of the reduced fat regular and instant creamers.

2. Material and methods

2.1. Chemicals and materials

Maltodextrin (DE = 10) was purchased from Roquette Freres Co. (Lestrem, France). Inulin (PubChem CID: 24763) was supplied by Cosucra Inc. (Fibruline Xl, Warcoing, Warcoing, Belgium). Silicon dioxide (PubChem CID: 24261) was purchased from Sigma Aldrich (St. Louis, MO, USA). Di-potassium hydrogen phosphate (PubChem CID: 6096956) was obtained from Nacalai Tesque Co. (kyoto, Japan). In addition, soy lecithin (Kordel's Co. CA, USA), commercial skim-milk powder (Dutch lady Co, Kuala Lumpur, Malaysia), hydrogenated palm kernel oil (PKO), corn syrup and vanilla (Melaka, Malaysia) were purchased from different suppliers in Malaysia.

Table 1
The composition of commercial creamers applied for comparison purposes.

Composition (g/100 g)	Commercial creamer
Fat	34.0
Carbohydrate	61.0
Protein	2.0

2.2. Preparation of creamer emulsion

Creamer emulsion was prepared according the following method: initially, the dispersed phase was prepared by mixing the hydrogenated palm kernel oil (8% w/w) and soy lecithin (emulsifier, 0.5% w/w) in a 100 mL beaker, covered with aluminum foil. Then, the mixture was heated at 80 °C and rotated at 100 rpm for 20 min in the thermo controller water bath. The aqueous phase was prepared by gradually dispersing sodium caseinate (2.5% w/w), silicon dioxide (as an anti-caking agent, 1.0% w/w), di-potassium hydrogen phosphate (as a stabilizer, 2.5% w/w), skim-milk powder (7% w/w) and corn syrup solid (15% w/w) into 100 mL hot distilled water (80 ± 5 °C). The solution was stirred with a magnetic stirrer at 100 rpm for 5 min to achieve lump free solution. Subsequently, different concentrations of maltodextrin (0%, 15%, 20% and 25%) and inulin (0.0%, 2.5%, 5.0% and 7.5% w/w) were gradually added to the aqueous phase to prepare different continuous phases. Then, it was continuously stirred at 100 rpm for 5 min at 60 ± 1 °C. In the last stage, the dispersed phase was gradually added to the continuous phase. Then, the mixture was gently stirred for 10 min to prepare the coarse creamer emulsion. Finally, the coarse emulsion was homogenized by a high pressure homogenizer (APV, Crawley, UK) at 200 and 180 MPa prior to drying. Finally, the homogenized creamer emulsion was dried by only spray dryer and/or spray dryer followed by fluidized bed dryer to prepare the regular and instant creamers, respectively. In this study, commercial creamer and control (0% inulin) were also considered for comparison purpose. It should be noted that fat plays a significant role in the sensory properties of coffee creamer. The coffee creamer with 100% fat replacement (0% fat) was also produced. Our preliminary analysis showed that the creamer with 0% fat did not provide any function like creamer after mixing with hot coffee.

2.3. Spray drying

The homogenized creamer emulsion was fed into a pilot scale mini spray dryer (BÜCHI model B-290, Flawil, Switzerland) (Fig. 1a). The sample was atomized with a rotary atomizer into the drying chamber with 1.2 m height and 0.87 m diameter. The recommended inlet and outlet temperatures for spray drying of thermo sensitive compounds are 180–220 °C and 90–110 °C, respectively (Kim, Chen, & Pearce, 2009). In the present study, the inlet and outlet air temperatures, pressure and feed flow rate were set at 180 ± 5 °C, 80 ± 5 °C, and 552 kPa and 10 (mL/min), respectively. A rubber toy was used to hint the drying chamber from outside as usual practice to collect more powder. This let to collect non-sticky powder from the drying chamber; while the very sticky powder cannot be taken by hinting drying chamber with a rubber toy. If the chamber is not hinted by the rubber toy, the production yield may