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Effect of oil content and drying method on bulk properties and stability of powdered emulsions with OSA starch and linseed oil

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ABSTRACT

The spray drying and freeze-drying of oil-in-water emulsions stabilized with tapioca OSA starch and trehalose (1:2), enabled producing high-fat powders (containing 40 and 55% of linseed oil). More effective microencapsulation of oil in powders with oil content above 50% was achieved by spray drying. The modification of oil content had no significant effect on the flowability of powders. Reconstitution properties of powders in water were significantly affected by the drying method. Turbidimetric measurement proved that the drying process did not cause any significant changes in the structure and physical stability of reconstituted emulsions. The application of powders as a savory creamer showed the lack of any substantial quality changes of color caused by water hardness. The peroxide value (PV) of microencapsulated linseed oil extracted from powders stored in barrier packages was higher than the PV of a control sample of bulk oil. Adverse changes of the UFA/SFA ratio, indicating the proportion between unsaturated and saturated fatty acids, were observed in oil extracted from stored powders.

1. Introduction

Soluble fat powders are usually produced by spray drying of oil-in-water emulsions (Desai & Jin Park, 2005; Gouin, 2004). Likewise milk powders, encapsulated plant fat powders can be applied as enriching components of many food products (Gibbs, Kermasha, Alli, & Mulligan, 1999).

The quality of encapsulated fat powders is indicated by the amount of fat not bounded in the structure of powder (the so-called "free" fat), the amount of occluded air filling up the volume of powder particles, and size of fat globules that together with carrier's matrix constitute a single powder grain. These properties affect the course of oxidative processes, flowability and solubility of powders (Calvo, Hernández, Lozano, & González Gómez, 2010; Frascareli, Silva, Tonon, & Hubinger, 2012; Huynh, Caffin, Dykes, & Bhandari, 2008). In the case of fat powder, additional quality requirements depend on the type and character of the finished product as well as on the function it is expected to serve in a food product. Powder applied as a creamer should be non-dusting as well as quickly and well dissolving. The main task of a creamer, after powder reconstitution in water, is mimicking sweet cream – imparting a creamy color. Such requirements will be met by the powder which, after reconstitution in water, will be reproducing the stable primary emulsion containing fine fat globules with diameters ranging from 0.5 μm to l0 μm (Bueschelberger, 2004; Lai, Tan, & Akoh, 2012, pp. 561–586).

A problem in using protein-fat powders as creamers is posed by flocculation which occurs as a result of emulsion degradation and protein precipitation upon high temperature, acidic pH and presence of salt or hard water (Scott, Duncan, Sumner, & Waterman, 2003). It may be avoided through the application of stabilizers and buffers in the form of phosphates and citrates that prevent protein precipitation, and through the addition of emulsifiers that are capable of complexating with protein, thus making it a more effective emulsion stabilizer (Ranjith Premlal, 2014; Alvarez, 2009).

An alternative means of producing creamers that would be stable with no need of using stabilizers and emulsifiers, may be production of fat powders through drying of oil-in-water emulsions stabilized with OSA starch (sodium octenylsuccinate starch). Many studies show that the application of OSA starch yields beneficial effects in the microencapsulation of bioactive lipid substances, including oils rich in polyunsaturated fatty acids (Serfert, Drusch, Schmidt-Hansberg, Kind, & Schwarz, 2009b; Anwar & Kunz,

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Abbreviations

F40L	freeze dried emulsion with 40% of linseed oil
F55L	freeze dried emulsion with 55% of linseed oil
F40R	spray dried emulsion with 40% of linseed oil
F55R	spray dried emulsion with 55% of linseed oil
DH	hardness of water
SD	standard deviation
DRY	dry method, factor of ANOVA
FAT	oil content, factor of ANOVA
η_p^2	size of effects of a given factor in the ANOVA analysis
NS	not significant, $p > 0.05$

2011; Dokić, Krstonošić, & Nikolić, 2012; Domian, Brynda-Kopytowska, Cenkier, & Świrydow, 2015a, Domian, Brynda-Kopytowska, & Oleksza, 2015b).

This study was aimed at analyzing selected properties of dry emulsions of linseed oil obtained with the method of spray drying and freeze drying, in the aspect of oil microencapsulation in the matrix of OSA starch with the addition of trehalose. The scope of the study included bulk properties of powders, physical stability of emulsions reconstituted from powders and oxidative stability of microencapsulated oil during storage of powders.

2. Materials and methods

2.1. Materials

The basic raw materials used in the study included: high-linolenic cold-pressed linseed oil (Oleofarm sp. z o.o., Poland); OSA starch (sodium octenylsuccinate starch) CAPSUL®TA, a modified food starch derived from tapioca starch (Ingredion Germany GmbH, Germany); and trehalose (Hayashibara, Japan).

2.2. Preparation of emulsions

The experimental material included four types of fat powders, containing 40 and 55% of linseed oil as well as tapioca OSA starch and trehalose in the ratio of 1:2, produced via spray drying and freeze drying of emulsions. Primary oil-in-water emulsions were prepared in the amount that allowed obtaining about 500 g of powders F40L, F55L, F40R and F55R with the raw material composition provided in Table 1. Emulsions were prepared by a two-step homogenization at 60/15 MPa in a high pressure homogenizer (Panda 2 K; Niro Soavi, Italy).

2.3. Spray drying of the emulsions

The spray drying of the emulsions was performed with a laboratory scale dryer (Mobile Minor, Niro A/S, Denmark). An inlet and an outlet air temperature of 150 ± 3 °C and 75 ± 2 °C were selected and disk rotation was at approximately 24,000 rpm. During drying, the outlet air temperature was controlled by emulsion feed rate which was 24–30 cm^3/min.

2.4. Freeze-drying of the emulsions

The emulsions were poured out on trays 36 cm in diameter to the height not exceeding 0.5 cm, and frozen at −70 °C in a Profi Master PMU0380 freezer (National Lab, Germany) for 24 h. The frozen emulsions were dried with a Gamma 1–16 LSC dryer (Christ, Germany). Dry emulsions were manual disintegrated and sieved to achieve powder with grain size below 2 mm.

2.5. Storage of powders

The fat powders were stored for three months in barrier foil packages tightly closed using a vacuum welding/packaging machine PP-5.4 (Tepro, Poland). Bags made of polyamide/polyethylene (PA/PE) foil (95 μm) welded 20 g served as unitary packages of the samples. In turn bags made of four-layer foil (lacquer, paper, aluminum, PE-LD low-density polyethylene), constituting a barrier to light, water vapor and air, served as collective package for 4 samples. Powder samples were stored in three variants of storage conditions: packaging in the non-modified atmosphere at 25 °C; packaging in the non-modified atmosphere at 6 °C; as well as vacuum packaging and 6 °C.

2.6. Analysis of powders

2.6.1. Moisture content

The moisture content (w) of the powder was determined gravimetrically by drying it in a vacuum oven at 70 ± 1 °C for 24 h (Vacuum oven VO200, Memmert, Germany).

2.6.2. Particle structure

The microstructure of the particles was investigated using a Hitachi TM3000 Tabletop scanning electron microscope (Hitachi High-Technologies Corp., Japan). Representative micrographs were selected for presentation.

2.6.3. Particle size distribution

A laser light diffraction instrument Cilas 1190 (Cilas, France) was used to determine particle size of the powders and oil droplet size of emulsions reconstituted from powder.

2.6.4. Density of particles

Apparent particle density (ρ) was determined using a helium pycnometer Stereopycnometer (Quantachrome Instruments, USA).

2.6.5. Bulk density, interstitial air in powder bed and flowability

Loose bulk density (ρ_L) and tapped bulk density (ρ_{T100} and ρ_{T500}) (packed with 100 and 500 standard taps) were determined using the jolting volumeter STAV 2003 (Engelsmann AG, Germany).

Table 1
Raw material composition of tested emulsions.

Emulsion	Method of drying	Composition of primary emulsion [%]				Composition of dry emulsion [% d.m.]		
		Linseed oil F	OSA starch S	Trehalose T	Water	Linseed oil F	OSA starch S	Trehalose T
F40L	L	16	8	16	60	40	20	40
F55L	L	22	6	12	60	55	15	30
F40R	R	16	8	16	60	40	20	40
F55R	R	22	6	12	60	55	15	30