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Microencapsulation of flaxseed oil by spray drying

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INTRODUCTION AND OBJECTIVES

Microencapsulation of oils in a polymeric matrix is an alternative that has been used by several researchers in order to protect unsaturated fatty acids against lipid oxidation, thus increasing oils shelf life. In the case of foods, the most common procedure for microencapsulation is spray drying.

According to Jafari (2008), the main factors that affect encapsulation efficiency of microencapsulated oils and flavors are: type of wall material, properties of the core materials (concentration, volatiliy), characteristics of the infeed emulsion (total solids, viscosity, droplets size) and conditions of the spray drying process (atomization type, inlet air temperature, air flow, humidity). Thus, it is important to optimize the drying process, in order to obtain the minimal surface oil in the powder particles.

The objective of this work was to study the influence of inlet air temperature, total solid content and oil concentration on the microencapsulation of flaxseed oil by spray drying, using gum Arabic as wall material. Encapsulation efficiency and lipid oxidation were analysed as responses.

MATERIAL AND METHODS

Material Flaxseed oil was purchased from Sabor da Terra (Bragança Paulista, Brazil), with the following fatty acid composition: 5.91% C16:0, 4.31% C18:0, 22.55 C18:1, 12.83% C18:2 and 53.55% C18:3.
Gum Arabic Instantgum BA® was kindly donated by Colloïdes Naturels Brazil (São Paulo, Brazil).

Preparation of emulsions The wall material was dissolved in distilled water under magnetic agitation, one day before emulsification. Coarse emulsions were prepared by blending the flaxseed oil and the wall solution, using a rotor-stator blender (Ultra-turrax IKA T18 Basic, Wilmington, USA), at 15500 rpm for 5 min.

Microencapsulation by spray drying Spray drying process was performed in a laboratory scale spray dryer LabPlant SD-05 (Huddersfield, England), with a 1.5 mm diameter nozzle and main spray chamber of 500 mm × 215 mm. The emulsion was fed into the main chamber through a peristaltic pump, feed flow rate was 12 g/min, drying air flow rate was 73 m^3/h and compressor air pressure was 0.06 MPa.

A rotatable central composite design was used to perform the tests for the microencapsulation of flaxseed oil, considering three independent variables: inlet air temperature, total solid content and oil concentration with respect to total solids. Five levels of each variable were chosen for the trials (Table 1), including the central point and two axial points, giving a total of 17 combinations. The following polynomial equation was fitted to data:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{33} x_3^2 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3 \quad (1)$$

Where β_n are constant regression coefficients; y is the response (encapsulation efficiency or lipid oxidation), and x_1, x_2 and x_3 are the coded independent variables (inlet air temperature, solid content and oil concentration, respectively).

Table 1 : Codified variables.

Variables	- α	- 1	0	+ 1	+ α
Inlet air temperature (ºC)	138	150	170	190	202
Solid content (%)	10	14	20	26	30
Oil concentration (%)	10	14	20	26	30

Encapsulation efficiency Surface oil was measured by extraction with hexane, followed by solvent evaporation. Total oil was assumed to be equal to the initial oil, since preliminary tests revealed that all the initial oil was retained, which was expected, considering that flaxseed oil is not volatile.

Encapsulation efficiency (EE) was calculated as follows: EE = (Total oil – Surface oil)/Total oil] × 100.

Lipid oxidation
or determination of the peroxide value (PV), the oil was extracted according to the method described by Partanen (2008). Lipid oxidation was determined spectrophotometrically, according to the IDF standard method with some modifications (Shanta 1994; Kellerby 2006; Partanen 2008). Results were expressed as meq peroxide/kg oil.

RESULTS AND DISCUSSION

The equations obtained for EE and PV were :

$$EE = 75.23 + 7.72x_2 - 11.13x_3 - 3.82x_2^2 \quad (2)$$
$$(R^2 = 0.927)$$

$$PV = 27.84 + 10.20x_1 - 9.65x_2 + 14.56x_3 + 9.41x_1^2 + 9.90x_2^2 + 9.69x_3^2 \quad (R^2 = 0.808) \quad (3)$$

The resulting models were tested for adequacy and fitness by the analysis of variance (ANOVA). They were suitable, showing significant regression, low residual values and no lack of fit.

Encapsulation efficiency Encapsulation efficiency varied from 51 to 92% and was significantly influenced by total solid content and oil concentration (Figure 1).

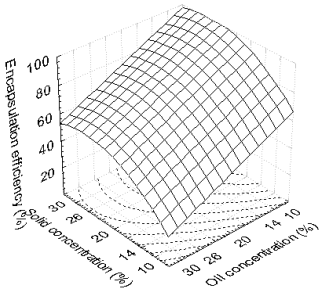
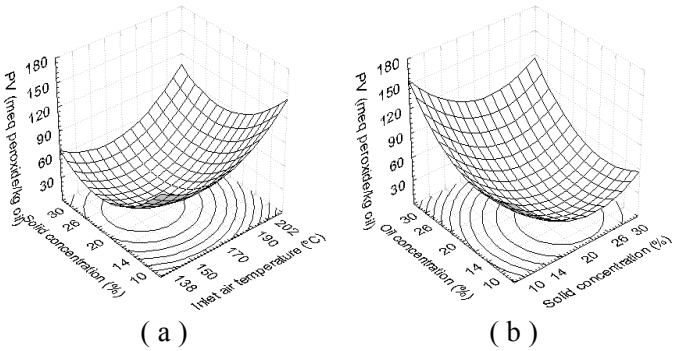


Figure 1 : Response surfaces for encapsulation efficiency of powders produced at T_{inlet} of 170ºC.

The higher the oil concentration, the lower was the encapsulation efficiency. This can be attributed to the greater amount of core material close to the drying surface, which makes short the diffusion path length to the air/particle interface, thus increasing the surface oil content. The negative effect of oil concentration on the encapsulation efficiency may also be related to the emulsion droplet size, which was lower for higher oil content (data not shown here). According to Jafari (2008), the greater amount of surface oil in the particles produced from emulsions with larger droplets can be attributed to the droplets breakdown during atomization.

Total solid content had a positive effect on the encapsulation efficiency, i.e., the increase in solid content resulted in higher encapsulation efficiency. Higher solid content implies in shorter time to form a crust, making difficult the oil diffusion to the drying particle surface. Moreover, increasing total solids leads to the increase of emulsion viscosity, reducing the circulation movements inside the droplets and, thus, resulting in a rapid skin formation (Jafari et al., 2008b).

Lipid oxidation The influence of inlet air temperature, solid content and oil concentration on the lipid oxidation is shown in Figure 2.



(a) (b)

Figure 2 : Response surfaces for lipid oxidation of powders produced : (a) with 20% oil and (b) at 170ºC.

Lipid oxidation was affected by all the independent variables. In general, lower solid content and higher oil concentration led to higher peroxide values. This can be related to the lower encapsulation efficiency obtained at these conditions, which leads to poorer oil protection against oxidation. The lower the encapsulation efficiency, the higher is the amount of oil present in the particles surface. This unencapsulated oil, when in contact with the oxygen, is much more susceptible to lipid oxidation than the encapsulated one.

Peroxide value also increased with increasing drying temperatures. The use of higher inlet air temperatures provides more energy available for the lipid oxidation process, which occurs more intensely, favouring the formation of peroxides.

CONCLUSIONS

Both encapsulation efficiency and lipid oxidation were affected by oil concentration and total solid content. Higher oil concentration and lower solid content resulted in poorer encapsulation efficiency and higher peroxide values. Lipid oxidation was also negatively influenced by the inlet air temperature. The conditions recommended for microencapsulation of flaxseed oil by spray drying were: inlet air temperature of 140-170ºC, solid content of 18-30% and oil concentration of 10-20%.

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