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Effect of carrier agents on the physicochemical properties of a spray dried chicken meat protein hydrolysate

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ABSTRACT

The spray drying of a chicken meat protein hydrolysate was studied in order to evaluate the effect of carrier agents on the physicochemical properties of the powders. The protein hydrolysate was obtained by enzymatic hydrolysis, which was carried out at 52.5 °C with a 4.2 g enzyme/100 g protein and a pH value of 8.0. The drying was carried out in a laboratory spray dryer, and maltodextrin and gum Arabic were used as carrier agents at three concentrations. Several physicochemical properties (moisture content, bulk density, distribution and mean diameter particle, hygroscopicity and glass transition temperature) of protein hydrolysate powders were measured. These results indicated that an increasing carrier agent concentration decreased the powder moisture content and bulk density. Mean diameter particle increased with increasing maltodextrin or gum Arabic concentration, which is related to the feed viscosity. The addition of maltodextrin or gum Arabic in the feed solution also contributed significantly to powder stability since powder hygroscopicity decreased and glass transition temperature increased with increasing carrier agent concentration.

1. Introduction

Whereas North and Central America and Europe have lost some shares in the market, China and Brazil have become the new centers for chicken production in Asia and South America, respectively. In recent years (2001–2006), Brazilian chicken meat production has increased by 37%, reaching almost 9 million tons in 2006 (FAOSTAT, 2008). According to Barbut (2002), novel processed poultry has been introduced onto the market over the last few years, due to low raw material prices. In order to be competitive, the poultry industry must develop new products to satisfy emerging consumer demands and increase profitability. Thus the hydrolysis of chicken meat protein could be an alternative solution to obtain value-added products. Chicken breast meat has a higher protein content (22 g/100 g meat) and lower fat content (3 g/100 g meat) than other parts of the chicken, such as the drumsticks (18 g protein and 5 g fat/100 g meat) and wings (18 g protein and 18 g fat/100 g meat) (TACO, 2004). In addition, chicken protein presents a perfect equilibrium of essential amino acids (Kurozawa et al., 2008).

Protein hydrolysates are mainly applied in the nutritional management of individuals who cannot digest whole/intact protein. Hydrolysates rich in low molecular weight peptides, especially di- and tri-peptides with as little as possible free amino acids, have been shown to have more dietary uses due to their high nutritional and therapeutic values (Bhaskar et al., 2007). Extensively hydrolyzed proteins also show reduced immunological reactivity, and can be used in formulas for hyper allergic infants (Mahmoud, 1994). Furthermore, peptides, being easily absorbed, may be an optimal nitrogen source in sports nutrition, and high biological value peptides are attractive as a general protein supplement in a wide variety of diets (Šližytė et al., 2005).

Due to their high protein content, hydrolysates are highly perishable and are therefore processed to improve their shelf life. Of the various methods employed for preservation, drying is a process in which the water activity of the food is reduced by removal of water through vaporization or sublimation, minimizing the enzymatic and microbiological reactions. Spray drying involves both particle formation and drying, where the feed is transformed from the fluid state into droplets and then into dried particles by spraying it continuously into a hot drying medium. This technique is widely used in food and pharmaceutical manufacturing and presents low operational costs and short contact time.

The addition of carrier agents (such as maltodextrins, gums, pectin, calcium silicate and carboxy-methyl cellulose) to the feed solution is important in the spray drying process, due to it influence on the properties and stability of the food powders. Maltodextrins are obtained by the hydrolysis of starch and have some advantages, such as: low cost and low viscosity at high solids ratios (Kenyon, 1995). Maltodextrin is mainly used in materials that are difficult to dry and has been used for tilapia protein hydrolysates

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Nomenclature

$D_{4,3}$	mean diameter particle (μm)
H	hygroscopicity (g/100 g solids)
T_g	glass transition temperature (°C)
X_{wb}	moisture content (%, wet base)

Greek letter

ρ_b	bulk density (kg/m^3)

and for mango, acerola and date palm pulps (Abdul-Hamid et al., 2002; Jaya and Das, 2004; Righetto and Netto, 2005; Sablani et al., 2008). Gum Arabic is a natural hydrocolloid produced by natural exudation from Acacia trees, and has been used as an encapsulating agent in microencapsulation by spray drying due to its good emulsifying capacity and low viscosity in aqueous solution (Thevenet, 1995). Its contribution to the stability of dehydrated foods was studied by Righetto and Netto (2005) and by Gabas et al. (2007), for acerola and pineapple juice powder, respectively.

According to Barbosa-Cánovas and Juliano (2005), the knowledge and understanding of properties is essential to optimize processes, functionality and reduce costs. Food powder properties can be classified as physical or chemical properties. Physical properties include the particle shape, density and porosity, surface characteristics, diameter and size.

Dried products are used mainly as convenience foods and have long storage life at normal temperatures. However, protein hydrolysates contain low molecular peptides, presenting low glass transition temperatures (T_g) and, consequently, high hygroscopicity and thermoplasticity. Since the T_g increases with molecular weight, the addition of carrier agents has been used in the production of powders, reducing the stickiness and wall deposition in spray drying (Roos and Karel, 1991; Bhandari et al., 1993). T_g is defined as the temperature at which an amorphous system changes from the glassy to the rubbery state. Molecular mobility in the glassy state is extremely slow, due to the high viscosity of the matrix (about 10^{12} Pa s). The T_g can be taken as a reference parameter to characterize the properties, quality, stability and safety of food systems. At temperatures above T_g, various physical properties are significantly affected by a consequent exponential increase on molecular mobility and decrease on viscosity. Molecular mobility and viscosity govern time-dependent structural alterations, such as stickiness, collapse and crispness. Moreover, at temperatures above T_g, the increasing molecular mobility improves diffusion, which may cause time-dependent crystallization of amorphous food components and increase rates of deteriorative changes (Roos and Karel, 1991; Roos, 1993).

The aim of this work was to evaluate the influence of maltodextrin or gum Arabic on the physicochemical properties (moisture, particle size, bulk density, morphology, hygroscopicity and glass transition temperature) of a chicken breast meat protein hydrolysate powder.

2. Materials and methods

2.1. Materials

Frozen chicken breast meat was purchased from Doux Frangosul Industry (Montenegro, Brazil).

For the enzymatic hydrolysis, the commercial protease Alcalase® 2.4 L (Novozymes, Bagsvaerd, Denmark), which is a serine endopeptidase obtained from *Bacillus licheniformis*, with a declared activity of 2.4 AU/g, was used.

The carrier agents used were maltodextrin Mor-rex® 1910, 10DE (Corn Products, Mogi-Guaçu, Brazil), and gum Arabic Instantgum® (Colloides Naturels, São Paulo, Brazil).

2.2. Preparation of the protein hydrolysate

The hydrolysis experiments were carried out in a 10 L thermostatically controlled stirred-batch reactor using the pH-stat procedure as described by Adler-Nissen (1985). The samples were defrosted overnight in a refrigerator at 4 °C. The tendons, nerves, skin and visible fat were removed from the meat, which was then fragmented, ground in a food processor and homogenized with distilled water (meat:water ratio 1:3 w/w). The mixture was heated to 52.5 °C and the pH value was adjusted to 8.00 with 2 N NaOH. The enzyme was added (4.2 g enzyme/100 protein) to the mixture and the reaction pH maintained constant by the continuous addition of 2 N NaOH. After 6 h the hydrolytic process was terminated by heating the mixture up to 85 °C and maintaining this temperature for 20 min, assuring inactivation of the enzyme. The process conditions were established according to the results obtained by Kurozawa et al. (2008). The resulting slurry was centrifuged at 3500 rpm (Beckman Coulter, Allegra 25R model, Fullerton, USA) for 20 min to separate the lipids. The protein hydrolysate was stored in a cold chamber at −18 °C and thawed according to the quantity required for spray drying.

2.3. Spray drying

Before the spray drying process, the carrier materials – maltodextrin (MD) or gum Arabic (GA) – were added directly (10, 20 and 30 g carrier agent/100 g feed solution, which correspond to 17.3, 26.0 and 34.6 g total solids/100 g feed solution, respectively) to the protein hydrolysate under magnetic agitation, until complete dissolution.

The spray drying process was carried out in a laboratory spray dryer (B191 model, Büchi, Flawil, Switzerland). The equipment was operated concurrently and a spray nozzle two-fluid atomizer with an orifice of 0.7 mm in diameter was used. The drying chamber had a diameter of 110 mm and a height of 435 mm. The protein hydrolysate (about 300–500 ml, varying between samples) was fed into the drying chamber through a peristaltic pump and the dried product (about 30–45 g, varying between samples) was collected for posterior analysis. The inlet air temperature was 180 °C and the outlet air temperature varied from 91 to 102 °C for each sample. The feed flow rate and compressed air flow rate were 0.2 kg/h and 0.6m^3/h, respectively.

2.4. Analytical methods

2.4.1. Proximate composition

The proximate composition (moisture, fat, protein and ash) of the chicken meat and the protein hydrolysate was obtained according to AOAC (1995). Moisture content was gravimetrically measured using a vacuum oven at 70 °C for 48 h. Ash content was determined using a muffle furnace at 550 °C for 24 h. Protein

and fat content were determined by Kjeldahl and Bligh and Dyer methods.

2.4.2. Particle size distribution

The particle size distribution was determined using a Mastersizer laser light scattering analyzer (model MAM 5005, Malvern Instruments Ltd., Worcestershire, UK). A small quantity of powder was dispersed in 99.5% ethanol and the particle distribution monitored during five successive readings. The particle size was expressed as the mean volumetric size $D_{4,3}$ (De Brouckere mean diameter), which is the mean diameter of a sphere with the same volume, and is generally used to characterize a particle.

2.4.3. Bulk density

The bulk density of the powders was measured by weighing 2 g of sample and placing it in a 50 ml graduated cylinder. The cylinder was tapped by hand five times and the bulk density was calculated by dividing the mass of the powder by the volume occupied in the cylinder (Goula and Adamopoulos, 2004).

2.4.4. Hygroscopicity

The hygroscopicity of the powders was determined according to Cai and Corke (2000) with some modifications. Samples (about 1 g) of each powder were placed in aluminum vials, weighed and equilibrated over a saturated salt solution NaCl (relative humidity of 75.3%, according to Greenspan (1977)) in desiccators at 25 °C. After one week, the samples were weighed and the hygroscopicity expressed as g moisture/100 solids.

2.4.5. Glass transition temperature

About 3 mg of protein hydrolysate powder were placed in differential scanning calorimetry (DSC) aluminum pans (20 μl) and equilibrated in desiccators at 25 °C and 32% relative humidity for one week (Cai and Corke, 2000). The samples were then hermetically sealed with lids for analysis, and weighed. The mass of each sample pan was matched in advance with the mass of an empty reference pan to within ±0.1 mg.

DSC analyses were carried out in a TA-MDSC-2920 (Ta Instruments, New Castle, De, USA). For temperatures below room temperature, a mechanical refrigeration system (RCS – Refrigerated Cooling Accessory) was applied. Equipment calibration was performed using indium ($T_{melting}$ = 156.6 °C) and verification with azobenzol ($T_{melting}$ = 68.0 °C). Dry helium, 25 ml/min, was used as the purge gas. After cooling the sample to −70 °C, the glass transition temperature was determined from thermo-analytical curves obtained by heating the sample at 10 °C/min to 80 °C. A second scan of each sample was carried out to reduce the enthalpy relaxation of the amorphous powder, which appears in the first scan. All analyses were carried out in triplicate, and the data were treated using the Universal Analysis 2.6 software (TA Instruments, New Castle, DE, USA).

2.4.6. Particle morphology

The particle structures of the protein hydrolysate powder were evaluated by scanning electron microscopy (SEM). The powders were attached to SEM stubs using double adhesive tape, coated with 3–5 mA gold/palladium under vacuum, and examined with a scanning electron microscope (Leica model LEO440i, Cambridge, England). SEM was carried out at 5 kV with magnification of x2000 and x5000.

2.5. Statistical Analysis

The results were analyzed by the Analysis of Variance and Tukey's Test at 5% significance, using the Statistica 5.0 (Statsoft, Tulsa, USA) software package.

3. Results and discussion

The proximate compositions of the chicken meat and the protein hydrolysate, obtained according to AOAC (1995), are shown in Table 1.

Table 2 shows the values for the moisture content, bulk density, mean diameter, hygroscopicity and glass transition temperature of the chicken meat protein hydrolysate powder.

3.1. Moisture

Analyzing Table 2, the powder moisture contents varied from 1.2% to 1.8% (wet basis), close to the values found by Tonon et al. (2008) and Papadakis et al. (2006), working with spray dried açai and raisin pulps, respectively. Increases in the carrier agent concentration resulted in decreases in the final powder moisture content. According to Goula and Adamopoulos (2004), in a spray drying system, the feed water content controls the residual moisture content in the powder. Lower final moisture contents can be reached by using higher feed solids contents, due to an increase in solids in the feed solution and reduced amounts of free water for evaporation. Moreover, maltodextrin and gum Arabic, due to their high molecular weight, are less hygroscopic. Consequently, the hygroscopicity of the final powder is reduced, resulting in lower powder moisture content. Abadio et al. (2004), Grabowski et al. (2006) and Goula and Adamopoulos (2004) observed similar behavior, studying the spray drying of pineapple juice with maltodextrin, amylase hydrolyzed sweet potato puree with maltodextrin and concentrated tomato pulp, respectively.

3.2. Particle size distribution

One of the most important physical parameters of powders is particle size. Particle size can influence the flow out of storage bins, the blending of different components, and compaction and segregation of a mixture, where smaller particles remain at the bottom and larger particles at the top. In addition, this property significantly influences the essential properties of food products, such as aroma, texture and appearance (O'Hagan et al., 2005). As the particle size decreases, so the increase in particle surface area causes greater affinity for moisture and the ability to agglomerate during the drying process (Tóth and Pallai-Varsányi, 2006).

Fig. 1 shows the particle size distribution of the powders. A bimodal distribution was observed for the protein hydrolysate formulated with additives, in which there are two distinct peaks, indicating two predominant sizes. One of them presented lower volume (<2%) and lower diameters particles (predominant sizes of 0.4–1.0 μm and 0.3 μm for powders formulated with maltodextrin (MD) or gum Arabic (GA), respectively) than another peak. The major peak, with larger volume and larger particle size, was different for each additive concentration. An increase in concentration resulted in wider curves: particles size of powders formulated with 10% and 20% MD varied between 2 and 35 μm; and between 2 and 70 μm for sample with 30% MD. For powders with 10, 20 and 30% GA, the particles distributions were between 0.8 to 35, 50 and

Table 1
Proximate compositions of the chicken breast meat and protein hydrolysate.

Analysis (%, wet basis)	Mean ± standard deviation	
	Chicken meat	Protein hydrolysate
Moisture	74.10 ± 0.14	91.32 ± 0.06
Protein	19.36 ± 0.94	7.05 ± 0.06
Fat	1.55 ± 0.12	0.08 ± 0.01
Ash	1.10 ± 0.01	0.68 ± 0.03

Table 2
Moisture content (X_{wb}), bulk density (ρ_b), mean diameter ($D_{4,3}$), hygroscopicity (H) and glass transition temperature (T_g) of the pure protein hydrolysate powder and of those formulated with maltodextrin (MD) or gum Arabic (GA).

Samples*	X_{wb} (%, wet base)	$D_{4,3}$ (μm)	ρ_b (kg/m^3)	H (g/100 g solids)	T_g (°C)
0%	1.8 ± <0.1aA	5.8 ± 0.1aA	383.9 ± 7.2aA	40.9 ± 2.4aA	1.3 ± 1.8aA
10% MD	1.5 ± <0.1b	8.9 ± 0.1b	330.2 ± 6.1b	23.1 ± 0.8b	49.2 ± 3.6b
20% MD	1.4 ± <0.1c	8.9 ± <0.1b	305.4 ± 1.6c	18.5 ± 0.4c	64.3 ± 1.5c
30% MD	1.2 ± <0.1d	13.4 ± 0.1c	295.6 ± 2.5c	15.9 ± 0.7c	67.7 ± 4.8c
10% GA	1.7 ± 0.1A	7.1 ± <0.1B	330.4 ± 13.3B	29.6 ± 0.4B	43.2 ± 0.6B
20% GA	1.5 ± 0.1A	7.7 ± 0.1C	311.9 ± 7.5B	24.6 ± 0.8C	52.6 ± 0.7C
30% GA	1.2 ± <0.1B	19.2 ± 0.2D	295.1 ± 8.2C	21.2 ± 0.3D	56.6 ± 1.3C

The values represent the means of three determinations ± standard deviations. Different letters indicate the samples are considered significantly different at the 5% level ($p < 0.05$). Lowercase and capital letters represent the response variation with maltodextrin or gum arabic concentration, respectively.
* The basis of percentage is g carrier agent/100 g feed solution.

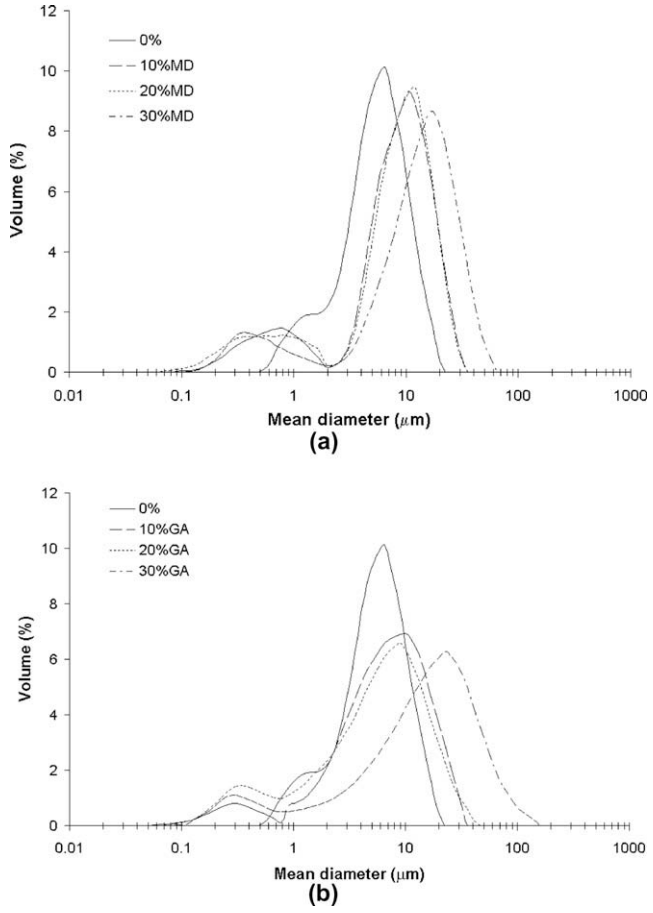

Fig. 1. Particle size distributions of the protein hydrolysate powders containing (a) maltodextrin (MD); and (b) gum Arabic (GA).

150 μm, respectively. Consequently, the predominant sizes increased with additive concentration: 10 μm for samples with 10% and 20% MD; 20 μm for samples with 30%MD. For powders formulated with 10%, 20% and 30% GA, the predominant sizes were 9, 10 and 25 μm, respectively.

On the other hand, the particle size distribution of pure protein did not present two separate peaks, but a distinct shoulder peak (predominant size of 1.5 μm) along with the main peak (predominant size of 6 μm). Probably, due to the stickiness of protein hydrolysate, there was formation of bridges between lower particles and, consequently, agglomeration, then increasing the particles diameter. Therefore, the first peaks, corresponding to the population of minor particles, could have been displaced to the right side of graphic, due to agglomeration and increasing of particles.

According to Tonon et al. (2008), bimodal distribution is important since smaller particles can penetrate into the spaces between the larger ones, thus occupying less space and increasing the powder bulk density. The presence of larger particles may be attributed to the start of the agglomeration process. The particle distribution of the pure protein hydrolysate (from 0.6 to 20 μm) was narrower than the distribution of samples formulated with maltodextrin (0.1 and 60 μm). For particles with gum Arabic, a greater particle distribution (0.1 to 150 μm) was observed.

The effect of the carrier agent concentration on the volumetric mean diameter $D_{4,3}$ is presented in Table 2, and as can be observed, an increase in feed concentration (0–30% MD or GA) led to an increase in powder particle size (5.8 μm for sample without carrier agent to 13.4 μm and 19.2 μm for samples with 30% MD and 30% GA, respectively). Similar behavior was observed by Cai and Corke (2000), Grabowski et al. (2006) and Tonon et al. (2008). In a spray drying system the size of the dried particles generally depends on the size of the atomized droplets. The droplet size is affected by the atomization model (rotary or nozzle atomizer), physical properties of the feed solution and feed solids concentration. The droplet size usually increases as the feed concentration or viscosity increases and the energy available for atomization decreases, resulting in the formation of larger particles (Goula and Adamopoulos, 2004).

3.3. Bulk density

Knowledge of the food density is of fundamental importance for studies with the properties of materials and industrial processes, in adjusting the storage, processing, packaging and distribution conditions. The bulk density is defined as the mass of the solid particles and included moisture, divided by the total volume occupied by the particles, surface moisture, and all the pores, closed or open to the surrounding atmosphere, and is generally used to characterize the final product obtained by milling or drying (Johanson, 2005; Barbosa-Cánovas and Juliano, 2005).

Table 2 shows that an increase in feed concentration (0–30% MD or GA) led to a decrease in powder density (383.9 kg/m^3 for sample without carrier agent to 295.6 kg/m^3 and 295.1 kg/m^3 for samples with 30% MD and 30% GA, respectively). Similar results were observed by Goula and Adamopoulos (2004) and Abadio et al. (2004) in the spray drying of concentrated tomato pulp and pineapple pulp with maltodextrin. According to Goula and Adamopoulos (2004), increasing the feed concentration generally decreases the bulk density due to the increase in particle size. This behavior can be observed when comparing the values for the mean diameter and bulk density shown in Table 2. According to Bhandari et al. (1992), an increase in feed solids concentration may lead to a reduction in particle density, probably due to a rapid surface crust formation at a certain solids concentration attained during the drying process. A vacuole forms within the particle soon after develops on the surface, and it inflates once the particle temperature

exceeds the local ambient boiling point and the vapor pressure within the vacuole rises above the local ambient pressure (Nijdam and Langrish, 2006).

3.4. Particle morphology

Figs. 2–4 show the SEM microphotographs of the spray-dried pure protein hydrolysate and those containing maltodextrin or gum Arabic, respectively.

As can be seen in Fig. 2, the pure protein hydrolysate presented spherical and smooth particles, with a formation of link bridges, due to its higher hygroscopicity. In Figs. 3 and 4, the particles presented various sizes and shapes (spherical, irregular and shrunk). Particles containing a carrier agent presented a continuous wall and the absence of surface cracks. Micrographs of the protein hydrolysate with 10% MD (Fig. 3a) revealed the formation of some spherical and smooth particles. However, the presence of larger numbers of irregular particles can be observed. Increasing the mal-

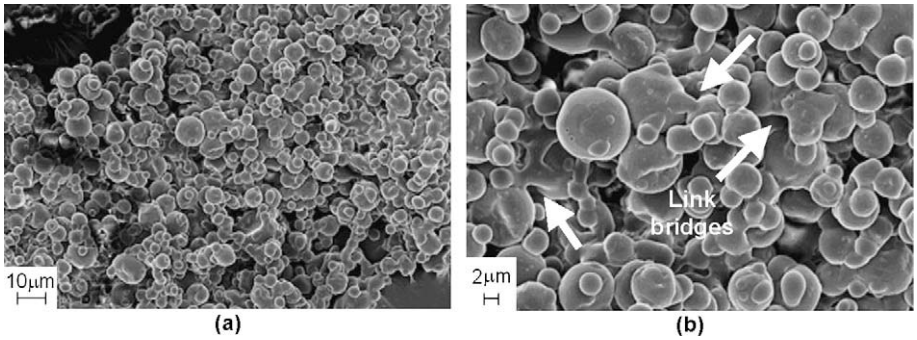

Fig. 2. Micrographs of protein hydrolysate powders without additives. Images with magnifications of: (a) 2000× and (b) 5000×.

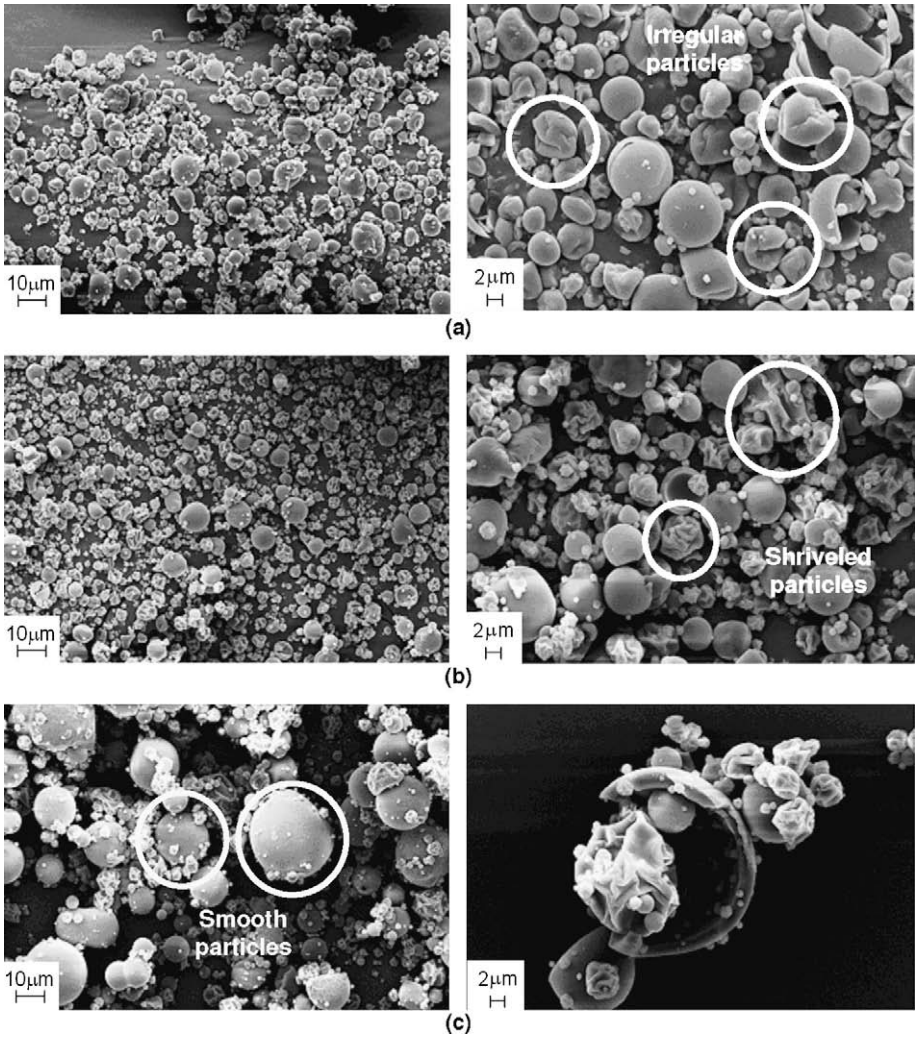

Fig. 3. Micrographs of protein hydrolysate powders formulated with maltodextrin: (a) 10%, (b) 20%, and (c) 30%. Images with magnifications of 2000× (left figure) and 5000× (right figure).

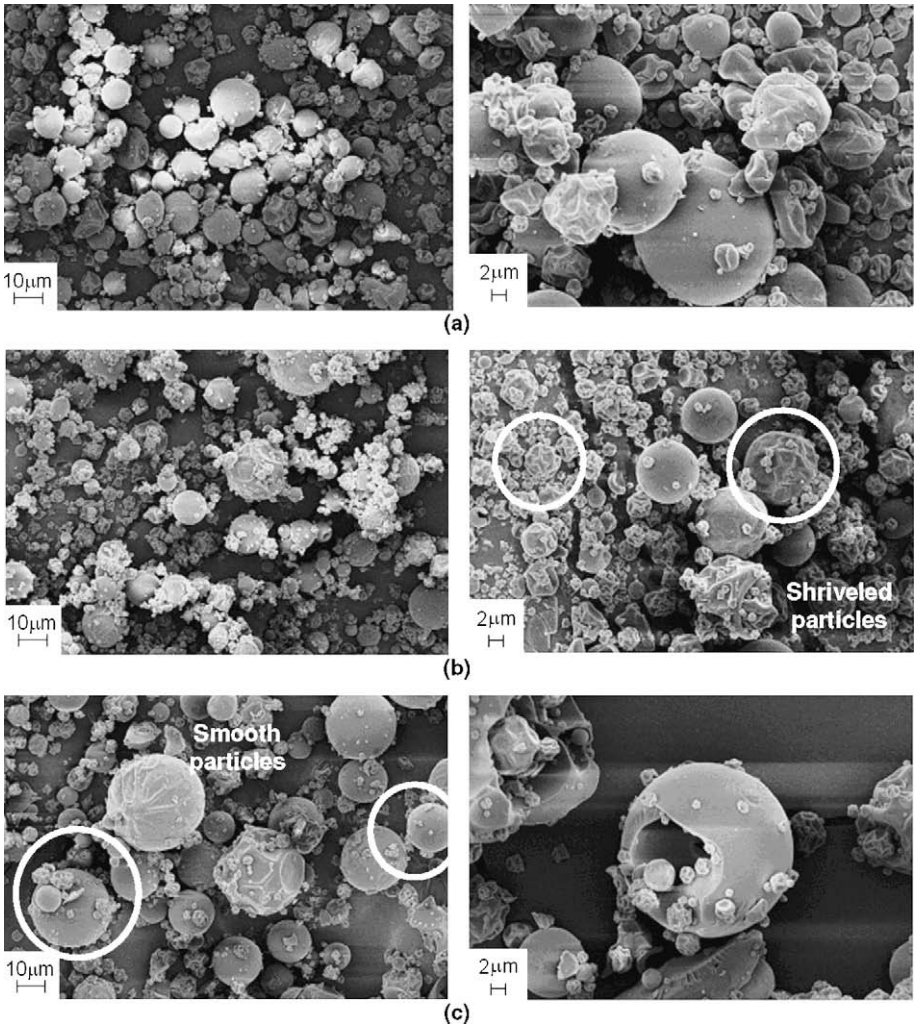

Fig. 4. Micrographs of protein hydrolysate powders formulated with gum Arabic: (a) 10%, (b) 20%, and (c) 30%. Images with magnifications of 2000× (left figure) and 5000× (right figure).

todextrin concentration (Fig. 3b and c), many particles presented a spherical shape with a shriveled surface. The same was observed for the particles containing gum Arabic (Fig. 4). Rosenberg et al. (1985) suggested that dents are formed by shrinkage of the particles during drying and cooling, and the presence of these dents has an adverse effect on the flow properties of powder particles. According to Ré (1998), surface imperfections, such as wrinkles, cracks or collapses occur when there is slow film formation during the drying of the atomized droplets.

The presence of spherical and hollow particles can also be observed in the Figs. 3b, c and 4c. Void formation may be related to several mechanisms connected to the atomization and drying processes in spray drying, such as: desorption of dissolved gases from the emulsion during drying and subsequent expansion; formation of a steam bubble within the drying droplet; or incorporation of air into the liquid drop during atomization (Rosenberg et al., 1985).

3.5. Hygroscopicity and glass transition temperature

According to Table 2, the addition of a carrier agent significantly affected powder hygroscopicity, which varied from 40.9 (for pure hydrolysate protein) to 15.9 g water/100 g solids (protein hydrolysate containing 30% of maltodextrin) and 21.2 g water/100 g solids (protein hydrolysate containing 30% of gum Arabic). Tonon et al. (2008) observed the same behavior for spray dried açai pulp. This may be due to the fact that the encapsulated protein hydrolysates contain low molecular peptides, and maltodextrin (mean value of 1800 g/mol) and gum Arabic (47,000–3000,000 g/mol) with high molecular weights (Pedroza-Islas et al., 1999). Since the glass transition temperature increases with increase in molecular weight, the addition of maltodextrin or gum Arabic to the feed solution contributed significantly to powder stability, increasing the T_g of the powder, and consequently reducing the stickiness.

Cai and Corke (2000) compared different average molecular weights of maltodextrin (10, 15, 20 and 25 dextrose equivalent – DE) on the hygroscopicity and T_g of amaranthus betacyanin pigments. From their results they concluded that as the molecular weight decreased, so the T_g of the spray-dried powders also decreased, whereas the hygroscopicity increased. According to the authors, the lower T_g obtained with high dextrose equivalent caused greater hygroscopicity of the powder, since the lower molecular weight maltodextrins contain shorter chains and more hydrophilic groups.

As expected, an increase in the concentration of the additives caused an increase in the T_g of the powders (Table 2). All amorphous products are metastable and are susceptible to caking, collapsing or crystallizing with time, during storage. The stability of these products is strongly associated with the T_g, which depends on the storage conditions such as water activity, humidity and temperature (Roos and Karel, 1991). Thus the T_g can be taken as

a reference parameter to characterize the properties, quality, stability and safety of food systems. Structural alterations occur in amorphous food powders when stored at temperatures above the T_g (Roos, 1993; Roos and Karel, 1991). Foodstuffs with low moisture contents and T_g values above the storage temperature can be considered stable. Thus, when the pure protein hydrolysate powder (T_g = 1.3 °C) was stored at a water activity of 0.32 (or relative humidity of 32%) and 25 °C, the powder suffered structural collapse. On the other hand, when maltodextrin or gum Arabic were added to the protein hydrolysate, the glass transition temperature values were bigger than the T_g of protein hydrolysate without carrier agent (Table 2), and the powders did not suffer caking under these storage conditions. Another problem visually observed during spray drying for the protein hydrolysate without carrier agent was the large amount of the powder stuck in the dryer chamber and cyclone. The T_g of protein hydrolysate powder without being equilibrated under saturated saline solutions, was 34.4 °C; and the outlet temperature (T_{out}) of the dryer was 91 °C, resulting in a higher ΔT value (where $\Delta T = T_{out} - T_g$). Since the addition of the carrier agent increased the T_g of the powder, there was a reducing on the ΔT, which in turn decreased the stickiness behavior.

The glass transition temperature (T_g) of the chicken meat pure protein hydrolysate (1.3 °C) is in good agreement with that reported for freeze-dried fish protein hydrolysate (0.6 °C, equilibrated under relative humidity 32%) (Aguilera et al., 1995). Hashimoto et al. (2004) observed higher T_g values for whole fish muscles. The difference in T_g values was over 50 °C. Shrestha et al. (2007) verified that whole lactose presented higher T_g (46.7 °C) values than hydrolyzed lactose (−3.5 °C), equilibrated under relative humidity 32%). The effect of different water activities on the T_g of osmotically dehydrated tilapia fillets obtained using binary or ternary solutions was evaluated by Medina-Vivanco et al. (2007). The glass transition temperatures found by these authors were higher (54.12 and 16.93 °C for osmotically dehydrated samples by NaCl and NaCl + sucrose solutions, respectively, equilibrated under relative humidity 32%) than that reported in this study, certainly due to their higher molecular weight proteins.

The effect of maltodextrin on the vacuum drying of mango pulp was verified by Jaya and Das (2004). According to these authors, drying of the sugar-rich mango pulp to a powder is difficult, due to the low molecular weight sugars and acids present in the pulp. These compounds have low glass transition temperatures, leading to stickiness of the powder. With the addition of maltodextrin to the system, the authors observed that the stickiness of the mango pulp powder decreased. Righetto and Netto (2005) verified the influence of maltodextrin and gum Arabic on the glass transition temperature of spray dried acerola pulp. The authors observed that the addition of 50% maltodextrin or gum Arabic increased the T_g of the pulp from 0.5 to 27.1 and 34 °C, respectively, at a water activity of 0.43. Sablani et al. (2008) observed that T_g of date powder vary from 12.7 to 47.5 °C when the proportion of maltodextrin:date increased from 35:65 to 50:50 (dry weight basis). Grabowski et al. (2006) reported that the addition of maltodextrin raised the glass transition temperature (values up to 12 °C above of the T_g of powder without maltodextrin) of the hydrolyzed sweet potato puree powder.

4. Conclusions

The effect of carrier agents on the physicochemical characteristics of a chicken meat protein hydrolysate was studied. The following properties: moisture content, bulk density, particle distribution and mean diameter; and the morphology, were affected by the addition of maltodextrin or gum Arabic. Also, the addition of the carrier agents was efficient in decreasing powder hygroscopicity, increasing its glass transition temperature, and consequently providing greater stability. The low T_g value (1.32 °C) and high hygroscopicity (40.95 g water/100 g solids) indicate the vulnerability of the pure protein hydrolysate powder during processing, handling and storage.

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