

Effects of different encapsulation agents and drying process on stability of betalains extract

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Abstract Red beet plants are rich in betalains that can be used as food natural colorants. Betalains were extracted from red beet and encapsulated with different carrier agents and freeze or spray dried. Effect of different encapsulating agents as maltodextrin, guar gum, gum Arabic, pectin and xanthan gum with different concentration (as encapsulating agents) were studied on the betalain stability. Encapsulated betalains with xanthan gum with maltodextrin showed about 65 % more recovery than the control. Encapsulation showed a higher recovery of betalains during freeze drying by 1.3 times than during spray drying. Spray dried samples has L* (lightness) higher than the freeze dried samples. The variations of maltodextrin with xanthan and guar gum freeze dried have highest chroma value of 21. The stabilization of pure betalain pigments may boost the use of these colouring molecules in the food industry and promote their application.

Keywords Betalains · Encapsulation · Extraction · Spray drying · Freeze drying · Stability

Abbreviations

| | |
|-----|-----------------------|
| MD | Maltodextrin |
| GA | Gum Arabic |
| Pec | pectin |
| GG | Guar gum |
| DE | (Dextrose equivalent) |

Introduction

Consumers are avoiding foods containing synthetic colorants which have lead to increased use of natural pigments in food industries (Azeredo 2009). Encapsulation of natural colors can be an interesting alternative for the replacement of artificial colorants for natural colorants in the food and pharmaceutical industry. Microencapsulation is a technique where in a bioactive compound is encapsulated by a biopolymer, protecting from oxygen, water or other conditions to improve its stability (Desai

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and Park 2005). Encapsulation promote easier handling and preventing lumping, improving flow ability, compression and mixing properties, reducing core particle dustiness and modifying particle density. It also enhances the shelf life of the natural colorants like betalains. The stabilization of betalains could be improved using micro-encapsulation technologies, such as spray drying (Desai and Park 2005). According to Altamirano et al. (1992) it was necessary to apply arabic gum and maize starch to the garambullo concentrate in order to avoid caramelization of the remaining sugars present in the extract of the pigment and to avoid its sticking to the walls of the drier. According to Cavalcanti et al. (2011) encapsulation is one of the main techniques to increase stability of anthocyanin. In food processing encapsulation is directly related to the coating of minute particles of ingredients as well as whole ingredients by micro encapsulation or macro encapsulation techniques. Encapsulation technology has been used in the food industry as a way to provide liquid and solid ingredients as an effective barrier for environmental and/or chemical interactions until release is desired. Microcapsules have the ability to preserve a substance in a finely divided state and to release it as occasion demands (Shahidi and Han 1993).

In food systems, microencapsulation prevalent objective is to protect the core material from degradation by reducing its reactivity to environmental conditions (Gibbs et al. 1999; Schrooyen et al. 2001). There are different kinds of encapsulating agents such as polysaccharides (starches, maltodextrins, corn syrups and arabic gum), lipids, proteins (gelatin, casein, soy and wheat protein) were used. The most commonly used material for microencapsulation are maltodextrins (Gibbs et al. 1999). Maltodextrins are starch hydrolysates that have important matrix-forming properties as wall materials (Chronakis 1998). According to Barbosa et al. (2005) typically used encapsulating materials are gum acacia, maltodextrins, hydrophobic starch, carboxy methyl cellulose and mixtures of them. Several materials such as starches, carboxy methyl cellulose, gelatin, maltodextrins, sodium alginate, sodium caseinate, pectin, gum Arabic, guar gum, chitosan etc. can be used for encapsulation. Several encapsulation techniques are used in food industries. Encapsulation of the secondary metabolites has great impact on their stability to higher temperatures such as in treatment like spray drying. Micro encapsulation is by which the secondary metabolites are coated with a thin film of protective material. They have more applications in the food industries as they increase the stability, increase the shelf life and easier to handle. Stability of betalains is promoted by its encapsulation in a maltodextrin matrix, a suitable spray-drying procedure for encapsulation result in stable free flowing powder, The stabilization of pure betalain

pigments increase the use of these bioactive and natural coloring molecules (Gandia-Herrero et al. 2010).

Natural colors present solubility problems during their use and may create dust clouds. Encapsulated colors are easier to handle and offer better solubility, stability and improves flow properties and reduces dusting when the nutrient are added to dry mixtures (Gibbs et al. 1999). The stabilization of pure betalain pigments may boost the use of these natural bioactive and colouring molecules in the food industry and promote their application in the pharmaceutical and cosmetic areas. Encapsulation can be performed by spray-drying, freeze drying, air suspension coating, extrusion, spray-cooling and spray-chilling, centrifugal extrusion, rotational suspension, simple and complex coacervation. The stability of betalains could be improved using spray drying (Desai and Park 2005). Spray-drying process has been used for decades to encapsulate food ingredients such as flavors, lipids, and carotenoids, in the drying process, evaporation of solvent, that is most often water, is rapid and the entrapment of the compound occurs quasiinstantaneously (Gharsallaoui et al. 2007). Desai and Park (2005) did a study of encapsulating vitamin C in tripolyphosphate cross-linked chitosan microspheres by spray drying whose efficiency increased up to 55 %. Spray drying is a well known industrial technology used extensively on a large scale for drying heat sensitive materials from liquid foods, most rapid liquid removal with minimal negative impact on the product (Sagar and Suresh Kumar 2010). According to Cai and Cork (2000) various carrier and coating agents significantly affect the properties and stability of spray dried powder and the best dried pigment containing was superior to commercial red beet powder. Spray dried powder colorant stored at room temperature, maintained 98 % of its color after one month (Obon et al. 2009). According to Fernando et al. (2006) betacyanins pigments quickly absorb humidity from the environment due its hydrophilic groups and the encapsulation with maltodextrin protects the pigment by allowing the drying process and also helps to reduce hygroscopicity by increasing their stability.

Maltodextrin as a wall material was used to produce a natural colorant in powder form from black carrot anthocyanins with spray drying technology (Ersus and Yurdagel 2007). Encapsulation of curcumin increased its stability against light, heat, pH and effectively improved its solubility (Wang et al. 2009).

Aim of our research The objective of this research was to study the effect of different encapsulating agents on stability and color of freeze or spray dried betalains. The results of this study would be helpful in establish the betalain encapsulation techniques for increasing its stability as powdered food grade colorants.

Material and methods

Materials

Sample preparation The fresh red beet plants were obtained from the local market in Berlin. The experiments were generally performed immediately after procurement.

Extraction of betalains

Red beet roots were washed and chopped into small pieces using magic mixture mechanical chopper. 1 g of chopped red beet was dissolved with 10 ml of distilled water then agitated in agitator (name) for 10 s and then centrifuged at 6000 rpm for 10 min. The supernatant was collected and the same procedure was repeated for two more times to ensure the maximum extraction.

Encapsulation

Red beet betalains extract was encapsulated with maltodextrin DE (Dextrose equivalent) 20 as the main carrier (control). Variations with other polysaccharides such as guar gum, gum arabic, pectin and xanthan gum were used as encapsulating agents combination with maltodextrin.

Methods of encapsulation

Encapsulation of betalains was prepared by mixing 100 ml of the extract with 20 g of maltodextrin DE 20 and was mixed homogeneously. This was labeled as control. For evaluating the encapsulating agents namely the gum Arabic, pectin, guar gum (GG1) and xanthan (xan1) xanthan gum was partially replaced instead of the maltodextrin by 1 g and as variation for guar gum (GG2) and xanthan (xan2) about 0.5 g was taken. The carriers were dry mixed thoroughly before mixing with the liquid extract. The mixtures were constantly and thoroughly stirred to ensure homogeneity during drying process.

Spray drying Spray drying process included dispersion of the core material in an entrainment material, followed by atomization and spraying of the mixture in a hot air desiccant into a chamber. The encapsulated mixtures were spray dried using Buchi Mini spray dryer B-191 (Switzerland). The spray dryer was operated at inlet temperature ranging from 90 to 102 °C. The air flow was 700 l/h, rate of feeding 10 ml/min and atomization pressure 25 psi. Encapsulated dry food color powder was obtained as end product.

Freeze drying The samples were frozen for 3 h at −18 °C. They were subsequently freeze dried for 2 days to ensure

complete drying (freeze drier Alfa-Christ, Germany). The final product was in dry powder form.

The encapsulated pigment powders were stored in 50 ml plastic airtight containers sealed with screw caps until further used and analysis.

Analysis of encapsulated betalains 1 g of encapsulated powder was dissolved in 10 ml of distilled water and homogenized with agitator for 10 s and centrifuged at 6000 rpm for 10 min and repeated for 2 more times to ensure maximum extraction of betalains. The supernatant was further used for determination of betalains. The content of betaxanthins and betacyanins in the extracts was determined spectrophotometrically at 538 nm and 480 nm using Jenway 6505 UV/Vis spectrophotometer, according to the methods of (Stintzing et al. 2004), pH was measured using CG 811. The soluble solid content °Brix was measured using Digital Refractometer RFM 80.

Color measurements Quantification of color was done with Minolta colorimeter (CR 200 Japan). Color in terms of luminosity, light versus dark (L*), red versus green (a*) and yellow versus blue (b*) were measured.

Statistical analysis

All analyses were performed in triplicate and data reported as mean ± standard deviation (SD). Data were subjected to analysis of variance (ANOVA) ($P < 0.05$). Results were processed by Excel (Microsoft Office 2007) and SPSS Version 17.0 (SPSS Inc., Chicago, IL, USA).

Results and discussion

In our study the effect of different encapsulating agents (maltodextrin, gum Arabic, pectin, guar gum, and xanthan gum) on the betalains stability and their influence on using spray and freeze drying techniques in combination with encapsulating agents were studied. In our study, all samples exhibited highly significant results. Apintanapong and Noomhorm (2003) supports the hypothesis that high DE maltodextrins and syrup solids permit the formation of encapsulated products with excellent stability to oxidation. In selecting the wall materials for encapsulation, maltodextrin is a good compromise between cost and effectiveness, as it is bland in flavor, has low viscosity at a high solid ratio and is available in different average molecular weights. Advantages of using polysaccharides include their solubility, bland flavor, low hygroscopicity and ability to protect bioactive compounds from oxidation.

Experimental data showed that encapsulation with maltodextrin greatly improves the stability of betalains to high degree and maintenance of the antiradical properties (Gandia-Herrero et al. 2010). Also with current experiment betalains are

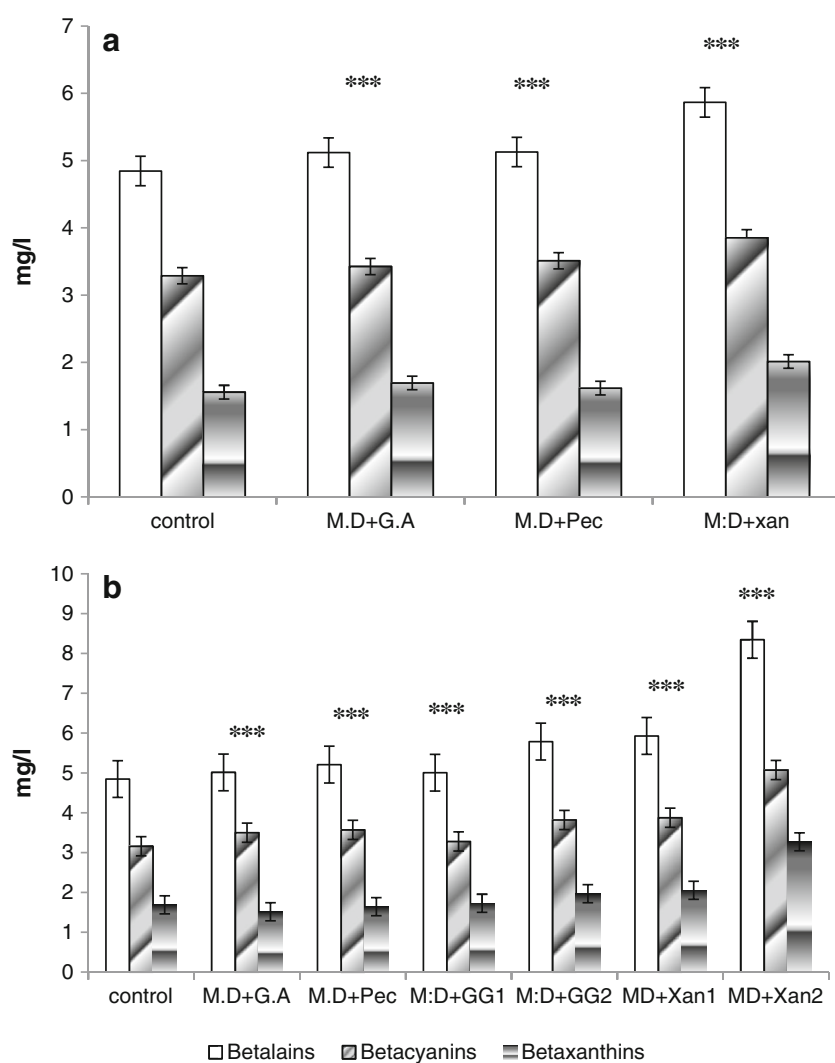
more stable when encapsulated, this results is comparable to the previous experiment. Different carrier concentrations improved dryer yield, and with gum Arabic being the most effective. Variation in anthocyanin is related to the type of carrier agent and its behavior during spray drying (Yousefi et al. 2011). Bioactive compounds (polyphenols and anthocyanins) of Pomegranate juice and ethanolic extracts were encapsulated with maltodextrin or soybean protein isolates by spray drying technique. The polyphenols encapsulating efficiency was significantly better when soya bean protein was used, whereas for anthocyanins was better with maltodextrin. Encapsulation with maltodextrin greatly improved their storage efficiency (Robert et al. 2010).

Figure 1(a) showed the results of spray drying for encapsulated sample variations. The samples encapsulated with pectin and gum Arabic showed a 6 % increased stability of betalains as compared control (maltodextrin alone). Interestingly with xanthan gum there was about 21 % more stability than control (Fig. 1a). Nevertheless, the pigment retention of the spray dried maltodextrin other variations was higher

than the control. The encapsulated samples with guar gum could not be spray dried. This may be due to high viscosity of guar gum and xanthan which made them not feasible to spray dry them, but with xanthan at lower concentration spray drying was possible.

However, in the case of freeze drying the encapsulation with guar gum and xanthan with normal concentration was possible. Microencapsulation of betalain with xanthan with lower concentraion showed better stability. Freeze drying results from (Fig. 1b) showed higher recovery of betalains. Variation with xanthan gum showed increase up to 65 % of betalains content than the control. Also the encapsulation with other variations such as pectin, gum Arabic and guar gum is slightly higher than the control by up to 3 % but, and 14 % increase in betalains content with guar gum variation but this was lesser than with xanthan gum. Encapsulation by spray drying is an economical method of preserving anthocyanin pigments by entrapping in a coating material (Cai and Cork 2000). They also added that the most common technique for encapsulation is with maltodextrins.

Fig. 1 Effect of different encapsulating agents on the content of spray dried (a) and freeze dried (b) betalains. Values are expressed as mean \pm SD; $n=3$; high significance of differences between treatments is indicated. M.D- maltodextrin, G.A – gum arabic, Pec- pectin GG1 (1 g) and GG2 (0.5 g) – guar gum as a replaced instead of the maltodextrin, xan1 (1 g) and xan2 (0.5 g) – xanthan as a replaced instead of the maltodextrin



Interestingly in our study we found that encapsulation of betalains with maltodextrin in combination with other gums increased the stability of betalains.

Freeze drying encapsulation with xanthan showed a higher recovery of betalains by up to 1.3 times than spray drying encapsulation. During spray drying there was increase in temperature which might have reduced the betalains content when compared to freeze drying in which the treatment was with lower temperatures. This might be the reason for the samples in freeze drying values were close to the control. Thermo sensitive substances that are unstable in aqueous solutions may be efficiently encapsulated by this technique. Freeze drying is a technique involves sublimation of ice fraction where water passes from solid to gaseous state. Because of very low temperature the deteriorating activity and microbiological activity are arrested and better quality final product is obtained (Sagar and Suresh Kumar 2010). Freeze drying stabilizes thermo sensitive substances efficiently. But, it involves long processing time; high process costs; expensive storage and transport cost. This can be explained by the fact that drying with lower temperatures is better for the stability of betalain than spray drying. Spray-drying is the most common and cheapest technique to produce microencapsulated food materials. Compared to freeze-drying, the cost of spray-drying method is 30–50 times cheaper (Desobry et al. 1997). Although in our study the betalains were better stabilized with freeze drying due to the advantages of spray drying, we suggest spray drying method as better choice.

The color is defined in the terms of luminosity (L), red versus green (a) and yellow versus blue (b). The results obtained for the different color values for different treatments were shown in the Table 1. Spray dried encapsulated samples visually appeared in extremely fine, colored water soluble powder. Various carrier and coating agents significantly affected the properties. Spray dried samples are lighter when compared to freeze dried samples.

With freeze drying lightness ranged from L^* 67.4 for encapsulation with pectin to 75.4 for xanthan sample. All the samples have positive a^* values as red color. Great dispersion was observed from the b^* parameter which is blueness- yellowness.

Chroma which expresses the purity of color was highest in freeze drying with encapsulation with guar gum and xanthan at high concentration 21 and also with gum Arabic with low concentration 16.4. The hue angle, which indicates the tonality, ranged in negative for encapsulation with guar gum and xanthan but positive for control, gum Arabic and pectin. Better color properties and anthocyanin content can be obtained by using maltodextrin as carrier, as the yield was more with Arabic gum, it seems better to use carriers in combination (Yousefi et al. 2011).

With spray drying the samples have same lightness and the variation with pectin and xanthan seems to be more on green side and also more yellow than the control and the variation with gum Arabic. While considering the hue all of them have negative values. But in freeze drying except for gum Arabic variation all other variations seems to have higher chroma value than the control. Freeze dried samples are darker than the spray dried samples but color stability is highest in freeze dried xanthan with maltodextrin.

Conclusion and outlook

Encapsulation with different carrier and gums show difference in the content of betalains retained and also they did show difference in color parameters. Various carrier and coating agents also affect the properties and storage stability of spray and freeze dried betalains. Encapsulation showed a higher recovery of betalains during freeze drying than spray drying. Guar gum could be encapsulated with freeze drying techniques but does not suitable in spray drying process.

Table 1 Effect of different encapsulating agents on the color of freeze and spray dried betalains; Values are expressed as mean \pm SD; $n=3$; M.D- maltodextrin, G.A – gum arabic, Pec- pectin, GG- guar gum, xan – xanthan GG1 (1 g) and GG2 (0.5 g) – guar gum as a replaced instead of the maltodextrin, xan1 (1 g) and xan2 (0.5 g) – xanthan as a replaced instead of the maltodextrin; light versus dark (L^*), red versus green (a^*), yellow versus blue (b^*), hue angle (H°), and Chroma (C^*) were measured. The main values with the same letter have no significant difference

| | L^* | a^* | b^* | H° | C^* |
|---------------|------------------------------|-----------------|------------------|------------------|-----------------|
| Spray Drying | | | | | |
| control | 86.1 \pm 0.00 ^a | 12.4 \pm 0.00 | –1.53 \pm 0.0 | –6.84 \pm 0.00 | 12.5 \pm 0.00 |
| MD + GA | 86.3 \pm 0.03 ^a | 12.1 \pm 0.01 | –2.01 \pm 0.05 | –9.37 \pm 0.39 | 12.3 \pm 0.00 |
| MD + PEC | 87.4 \pm 0.03 ^b | 10.1 \pm 0.04 | 0.3 \pm 0.14 | –1.72 \pm 0.99 | 10.1 \pm 0.04 |
| MD + Xan 2 | 86.1 \pm 0.30 ^a | 11.4 \pm 0.25 | –1.57 \pm 0.01 | –7.77 \pm 0.32 | 11.6 \pm 0.25 |
| Freeze drying | | | | | |
| control | 74.1 \pm 0.46 | 17.8 \pm 0.26 | 1.06 \pm 0.01 | 3.43 \pm 0.00 | 17.8 \pm 0.26 |
| MD + GA | 75.0 \pm 0.68 | 16.2 \pm 0.28 | 2.69 \pm 0.07 | 9.64 \pm 0.00 | 16.4 \pm 0.30 |
| MD + PEC | 67.4 \pm 1.04 ^a | 17.7 \pm 2.12 | 3.50 \pm 0.36 | 11.30 \pm 0.00 | 18.0 \pm 2.15 |
| MD + GG1 | 72.0 \pm 0.07 ^c | 21.0 \pm 0.15 | –0.4 \pm 0.04 | –1.14 \pm 0.00 | 21.0 \pm 0.15 |
| MD + GG2 | 68.5 \pm 0.13 ^b | 21.6 \pm 0.04 | –1.28 \pm 0.04 | –3.43 \pm 0.00 | 21.7 \pm 0.04 |
| MD + Xan 1 | 71.3 \pm 0.04 ^c | 21.2 \pm 0.09 | –1.11 \pm 0.06 | –3.05 \pm 0.33 | 21.2 \pm 0.09 |
| MD + Xan 2 | 75.4 \pm 0.06 | 19.0 \pm 0.08 | –1.09 \pm 0.03 | –3.43 \pm 0.00 | 19.0 \pm 0.08 |

Although the stability of spray dried betalains was low when compared to freeze dried one, it involves low process cost, wide choice of coating material; good encapsulation efficiency and good stability of the finished product which possibility makes it suitable for large-scale production in continuous mode. This study demonstrated the feasibility of production of spray dried and freeze dried betalains extracts with combination of encapsulating carrier agents as an effective food grade colorant. The present work proposed an extraction and encapsulation method which is simple and reliable, a stable concentrated free flowing powder with high color strength. The red beet betalains encapsulated represent a promising food additive for incorporation into functional foods, due to its red color which are stable after treatment.

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