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Microencapsulation and Oxidative Stability of Ginger Essential Oil in Maltodextrin/Whey Protein Isolate (MD/WPI)

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Abstract: The extent of oxidation in a sample of oil can be expressed in terms of surface oil and peroxide value. The effect of wall compositions on the surface oil was studied using the washing method and the peroxides produced by oxidation of the oil were measured based on the ability to liberate iodine from potassium iodide. Peroxide value is determined by measuring iodine released from potassium iodide. Microcapsules were stored at 35°C at different water activities (a_w). Oxidation was monitored by measuring the peroxide values. The changes in the amount of encapsulated oil were determined by Clevenger hydrodistillation. The ratios maltodextrin/whey proteins isolate MD: WPI (1:1) and Core: wall (1:4) with 30% solid content produced the lowest surface oil (0.07 g/100 g) and showed good storage life. Microcapsules stored at a_w in the range of 0.58 to 0.76 had a good stability against oxidation for at least 35 days. Therefore, MD/WPI is considered as an effective microencapsulating agent.

Key words: Microencapsulation, water activity, oxidative stability, surface oil, whey protein, maltodextrin

INTRODUCTION

Ginger is widely used as a flavoring agent in beverages and many food preparations. The medicinal history of ginger is extensive. Ginger has played an important role in Chinese, Indian and Japanese medicine and has developed a reputation in the treatment of many gastrointestinal disorders hence is often promoted as an effective herbal antiemetic. Ginger has long been believed to possess anti-inflammatory, cholesterol-lowering and anti-thrombotic properties. Today, ginger is perhaps most popular in the United States for treating nausea and vomiting associated with motion sickness (Yamahara and Huang, 1990).

The medical science of nausea is complicated with coexisting disease states. Safe practical choices in essential oil therapy can be extrapolated from evidence based clinical references, which may be integrated into the medical management of various conditions. Specifically, the naso-cutaneous application of essential oil of ginger, *Zingiber officinale*, can be a safe and effective addition to the medical management for the prevention and treatment of the complications of nausea and vomiting associated with general anaesthesia (James and Geiger, 2005).

Ginger essential oil has many beneficial biological effects. The prevention of its oxidative deterioration must be considered when ginger oil is prepared, stored and used as a dietary supplement.

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Microencapsulation is a technique in which a membrane encloses small particles of solid, liquid or gas, to protect the core material from adverse environmental conditions such as undesirable effects of light, moisture and oxygen, thus contributing to increase the shelf life of the product and controlled release of encapsulated material (Shahidi and Han, 1993). Microencapsulation of ginger essential oil has the potential to improve its oxidative stability and can improve its handling and use by making it a shelf-stable powder. The stability of microencapsulation material is influenced by the composition of the wall. Maltodextrin (MD) and Whey Protein Isolate combinations were used as wall material in microencapsulation in spray drying.

It has generally been accepted that the shelf-life is related to surface oil. The logic being that the surface oil is not protected from oxygen and readily undergoes oxidation during storage. The high surface oil is a major problem affecting the shelf life during storage. High surface oil did not correspond to lower shelf life. Thus, it appears that surface oil is not the primary determinant of oxidative stability and for this reason the peroxides produced by oxidation of the oil was also studying.

The objective of this study was to evaluate the performance of maltodextrin/whey protein isolate (MD/WPI) as a wall material and its effect on surface oil in microencapsulated ginger essential oil using the spray-drying technique and to monitor the oxidative stability of microcapsules stored at different water activities (a_w) at 35°C.

MATERIALS AND METHODS

Fresh ginger (*Zingiber officinale*) obtained from the local supermarket Wuxi, China (2007), were frozen and chopped in small pieces, of approximately 2 mm homogenized in distilled water using a domestic blender. Ginger oil was extracted by steam distillation using a vertical steam distillation unit (AOAC, 1995), as it was found to give a simple and effective method to obtain essential oils from plants (Lawrence, 1998). Whey Protein Isolate (WPI) was purchased from New Zealand Milk Product (Fonterra Ltd., Auckland, New Zealand). Maltodextrin (MD) with a Dextrose Equivalent (DE) of 18 was purchased from Xiwang Starch Co. Ltd (Binzhou, China). Food grade solvents and chemicals were obtained from chemical store of SYTU.

Emulsification and Spray Drying

Wall solutions consisting of mixture of WPI and 18DE MD were prepared in deionized water (25°C) and then cooled to 4°C. In all cases, the solid content of wall solutions was 20, 25 and 30% (w/w). MD: WPI weight ratios of 3:1, 2:1 and 1:1; Core: Wall weight ratios of 1:2, 1:3 and 1:4 were used. Ginger essential oil (4°C) was emulsified into the wall solutions at different solid content using the conditions described above. The mixture was prepared using an Ultra Turax T-25 high-shear mixer (IKA Works, Cincinnati, OH-USA) operated at 11,500 rpm for 2 min. The second stage consisted of two successive homogenization steps using a Mini-Lab high pressure homogenizer, operated at 30 Mpa and was immediately fed to a Niro Utility Model spray drier (GEA Process Engineering China Ltd., China) equipped with a centrifugal wheel atomizer. The drying conditions were an inlet and outlet air temperature of 120±3 and 60±3°C, respectively.

Surface Oil Determination

The volatile compounds retained on the surface of particles were determined by washing about 5 g of powder (in duplicate) with 20 mL of diethyl ether. This solvent powder mixture was gently shaken manually or using a magnetic stirrer for 20 min. The mixture was filtered and solvent was evaporated with a rotary evaporator (R501B Sisters, China) at 25°C. The surface oil was determined by weighing the oil.

Retention of Volatiles

The change in ginger oil content of the microcapsules was studied by the hydrodistillation method. This parameter was monitored until equilibrium was achieved. The retention of ginger oil by the microcapsules after storage at different water activities was expressed as a percentage of the initial ginger oil.

Oxidative Stability

Samples (20 g) were placed in desiccators containing saturated salt solutions [N_aB_r, $(NH_4)_2SO_2$ and Z_nSO_4] at different water activities (a_w) of 0.58, 0.76 and 0.90, respectively and stored for 5 weeks at 35°C.

Analysis of Oxidative Stability

Peroxide values (Pv) of the sample were determined by the AOCS (1992) method. Briefly, 10 mL of acetic acid/Chloroform mixture (3:2, v/v) was added to the sample in 250 mL Erlenmeyer flasks and stirred for 2 min with a magnetic stirrer to exclude Ginger Essential Oil (GEO) from the GEO/MD/WPI microcapsules. One milliliter of saturated KI solution was added into the Erlenmeyer flasks and stirred for another min, followed by the addition of 10 mL distilled water. The sample was titrated with 0.1 N sodium thiosulfate standardized, using a starch solution (5% heat to disperse). A blank test was also conducted. Pv was calculated using Eq. 1:

$$Pv(meq/kg) = \frac{(S-B)\times 1000\times N}{W} \quad (1)$$

Where S and B are the mL of sodium thiosulfate solution consumed by sample and blank tests, respectively, N is the standardized normality of sodium thiosulfate.
W is the weight of sample (g).

Statistical Analysis

ANOVA was performed on mean values of the analytical results. Differences were considered to be significant at $p<0.05$

RESULTS AND DISCUSSION

Surface oil content of the dried products ranged from 0.07 to 0.29 g/100 g of powder (Fig. 1). Surface oil content is strongly related to the emulsion droplet size and low surface oil content is important for providing storage stability to the encapsulated materials Kagami *et al*. (2003). As it can be seen in Figure 1, the wall composition C and B had the lowest surface oil of 0.07 and 0.14 g/100 g of powder, respectively, while wall composition A (0.29 g/100 g of powder) had the highest surface oil. It has generally been accepted that shelf-life is related to surface oil.

The wall composition C [MD/WPI (1:1); Core/W (1:4) at 30%] yielded best and approximately equivalent shelf-life. The logic being that the surface oil is not protected from oxygen and readily undergoes oxidation during storage. This observation supports the work of Bangs and Reineccius (1990) who found that encapsulated orange oil will oxidize at approximately the same rate as the equivalent product which had been washed with the solvent to remove any surface oil. These results were in agreement with a previous investigation that showed that the presence of low levels of surface oil in encapsulated orange oil samples yielded only slightly higher oxygen absorption rates as compared to the same samples in which the surface oil had been removed Bangs and Reineccius (1990).

The retention and stability of the microcapsules were affected by water activity and storage temperature. The results obtained are shown in Fig. 2.

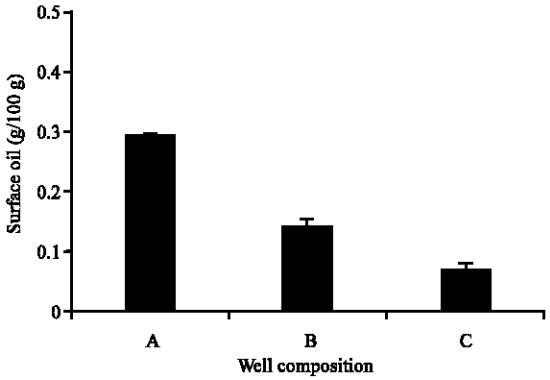

Fig. 1: Effect of wall composition on surface oil. A) [MD/WPI (3:1); Core/W (1:2) at 20%]; B) [MD/WPI (2:1); Core/W (1:3) at 25%]; C) [MD/WPI (1:1); Core/W (1:4) at 30%]. Each data represents the mean of observations on three preparations. Bars represent standard errors of the mean. MD/WPI = maltodextrin/whey protein isolate; Core/W = core/wall

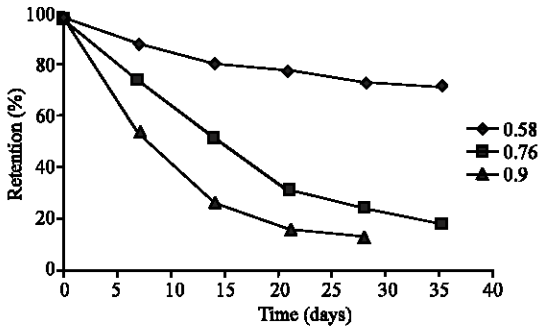

Fig. 2: Retention of ginger oil encapsulated in maltodextrin/whey protein isolate as a function of time at a different water activities at 35°C

Figure 2 depicts the retention of ginger oil by spray-dried MD/WPI microcapsules as a function of storage time at different water activities at 35°C. At a_w 0.58, in the first week, 10% of the initial ginger oil was lost and at a_w 0.76 and 0.90 the retention decreased to 75 and 55%, respectively. After 4 weeks, samples at a_w 0.90 caused progressive dissolution of the polymer wall and suffered total loss of ginger oil. Similar results were found by Rosenberg *et al.* (1990) for retention values of ethyl butyrate using gum Arabic as encapsulating agent.

The peroxide values (Pv) of samples stored at different water activities for 35 days at 35°C are depicted in Fig. 3. Microcapsules at 35°C showed an increase in peroxide values from 2.7 to 4 meq kg^{-1} oil as the water activity decreased from 0.90 to 0.58. Peroxide values increased during 4th week (Fig. 3). Then, Pv reached a plateau between the 4th week and the 5th week (end experiments). It suggested that microcapsules held at low a_w could develop a porous or a cracked surface permitting penetration of oxygen, causing greater production of peroxides and degradation of ginger oil, contributing to the increase in the peroxide values. Kim *et al.* (2000) used the peroxide values as a measure of the oxidative stability. They found CLA/α-CD microcapsules at a 1:4 molar ratio completely protected CLA from oxidation over 80h at 35°C without controlling the water activity. The smallest Pv of the microcapsules was obtained when the samples were stored at a water activity of 0.90 and at 35°C.

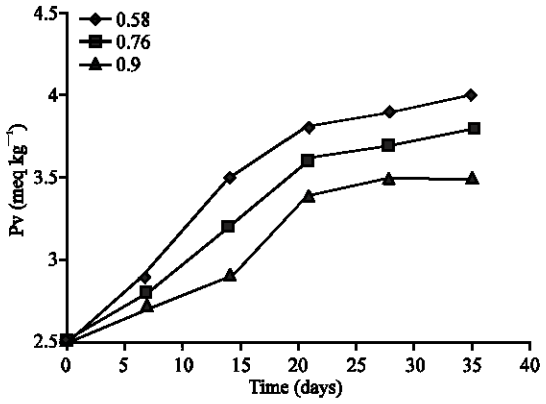

Fig. 3: Peroxide values for ginger oil encapsulated in maltodextrin/whey protein isolate stored at different water activities at 35°C

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CONCLUSION

This study supports the hypothesis that the mixture of 18DE MD and WPI showed very good ability for ginger oil microencapsulation, providing excellent stability and effective protection against oxidation. The stability of the microcapsules was affected by water activity and storage temperature. The best stability was obtained at a_w 0.76 at 35°C, under which conditions the sample were stable to physical changes and the ginger oil degradation was 25%. This suggested that the low surface oil did not adversely affect shelf life of microencapsulated ginger oil.

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