Physicochemical Assessment of Curcumin Microencapsules Containing Maltodextrin and Gelatin Coatings

Humaira Ashraf[1,*], Masood Sadiq Butt[2], Ali Asghar[3]

[1]Department of Food Science and Technology, Jinnah University for Women, Karachi, Pakistan

[1,2,3]Faculty of Food Nutrition and Home Sciences, National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan

*E-mail humairaagri@gmail.com

ABSTRACT

Contemporary consumer's trends showed the popularity of phytoceutics coupled with dietary interventions because of their influence on human health. There are strong evidences supportive to the occurrence of phytoceutics in spices and their inclusion in diet improves hedonic response besides acting as natural defensive agents. The clinical and food applications for "curcumin" one of the turmeric bioactive moieties, are restricted owed to its low water solubility, insufficient residence time, high degradation, less absorption rate and rapid metabolism & elimination from gastrointestinal tract. However, packaging insoluble core material into capsule varying in size from one micron to more than a few millimeters preserves integrity of lipid soluble material under acidic/alkaline conditions. The instant study was designed to overcome these disparities using maltodextrin (15, 20g) and gelatin (2, 4, 6g) as enrobing materials at different ratio to achieve best combination for curcumin, isolated from turmeric using conventional solvents (etanol, methanol & acetone) and supercritical fluid (CO2). Results were assessed by recording encapsulation efficiency and in vitro solubility of each treatment. Amongst various blends of coating materials, encapsulate supercritical fluid extracts containing 20 g maltodextrin and 6 g gelatin was owing to its encapsulation efficiency & in vitro solubility 73.58±3.16% & 4.73±0.23 mg/mL, respectively. Thus, microencapsulation of turmeric active ingredient extracted under supercritical conditions proved one of the promising techniques to tackle the current dilemma.

Keywords: Curcumin, maltodextrin, gelatin, supercritical fluid, encapsulation.

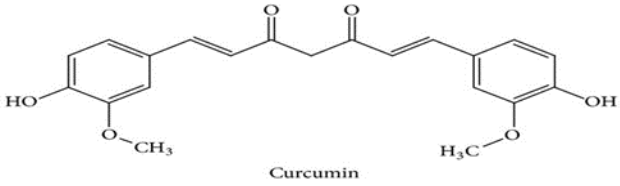
INTRODUCTION

Turmeric (*Curcuma longa L.*) is a rhizomatous perennial herb, having its place to "*Zingiberaceae*" family. The main active compounds of turmeric are curcuminoids and essential oils. The turmeric bioactive moiety "curcumin" is being extensively utilized as coloring agent but its food applications are limited owing to its limited stability and solubility (White *et al*., 2019). Moreover, for therapeutic potential, accessibility of bioactive moiety at targeted site within the body is very crucial. Generally, there are three factors namely solubilization, absorption and metabolism that strongly effect the bioavailability of compounds. Curcumin is water insoluble in nature hence undergoes rapid metabolism in gastrointestinal tract as well as in liver resultantly degraded into conjugated metabolites such as glucuronide and sulfate (Bhowmick *et al*., 2009).

In this context, hydroxyl groups at phenolic ring are more susceptible to glucuronidation resulting in the formation of lipophilic conjugates that readily eliminate with stool. This problem could be resolved by encapsulating bioactive molecules in different types of wall materials either singly or compatible biopolymers (Aggarwal and Sung, 2009; Xie *et al*., 2011).

Microencapsulation is among the latest approaches to pack the insoluble materials in miniature that enhance the bioavailability of core material at controlled rate. Actually, microcapsules are small particulates ranging in

size from sub-micron to various millimeters. Different methods are employed to encapsulate insoluble material at micro level including spray drying, extrusion, coacervation, lyophilization and microemulsion (Fang and Bhandari, 2010; Chen *et al*., 2020). To counteract this difficulty, curcumin is encapsulated using wall material comprised of hydrophilic groups like maltodextrin and gelatin.



Curcumin

OBJECTIVES

- Assessing the efficiency of curcumin microencapsulates on the basis of entrapment capacity and in vitro solubility.

METHODOLOGY

The instant research was conducted at National Institute of Food Science and Technology (NIFSAT), University of Agriculture, Faisalabad (UAF), Pakistan. In the present investigation, locally available turmeric variety (Kasur) was used for the extraction and encapsulation of curcumin at micro scale. Analytical grade reagents were acquired from Sigma-Aldrich (Sigma-Aldrich Tokyo, Japan) and Merck (Merck KGaA, Darmstadt, Germany).

Preparation of Turmeric Extracts

Conventional Solvent Extraction (CSE)

The treatments used in the study were prepared using ethanol (50% v/v), methanol (50% v/v) and acetone (50% v/v) each at three different time intervals: 35, 50 and 65 min with constant temperature of 50oC following the prescribed procedures of Kulkarni *et al*. (2012).

Supercritical Fluid Extraction (SFE)

Supercritical fluid extracts of dried turmeric rhizome were obtained using SFT-150 system employing 99.8% pure CO2. Afterwards, the sample is placed in 100 mL extraction vessel, CO_2 was liquefied by optimizing at three different time intervals i.e. 50, 100 and 150 min while keeping pressure and temperature conditions constant to speed up the solvation and mass transfer of curcumin (Wakte *et al*. 2011).

Microencapsulation of Curcumin

Curcumin extracted using conventional solvents and supercritical fluids were encapsulated (Table **1**) using homogenous emulsions comprised of various proportions of maltodextrin (15 & 20 g) as well as gelatin (2, 4 & 6 g) as mentioned in Table 2 according to prescribed method of Malacrida and Telis (2011). The resultant material was finely ground and stored for further analysis.

Encapsulation Efficiency (EE)

The prepared microcapsules were tested for their entrapment capacity depending on the total curcumin contents following the protocol of Malacrida and Telis (2011). The curcumin content was calculated using the standard curve.

Encapsulation efficiency (EE%) was expressed as:

$$EE\% = (CE/C0) \times 100$$

CE= curcumin content in the freeze dried powder

C0= curcumin content in emulsion

Treatments	Maltodextrin (g)	Gelatin (g)
$\mathbf{T_{1CSE}}$ $\mathbf{T_{1SFE}}$	15	2
$\mathbf{T_{2CSE}}$ $\mathbf{T_{2SFE}}$	15	4
$\mathbf{T_{3CSE}}$ $\mathbf{T_{3SFE}}$	15	6
$\mathbf{T_{4CSE}}$ $\mathbf{T_{4SFE}}$	20	2
$\mathbf{T_{5CSE}}$ $\mathbf{T_{5SFE}}$	20	4
$\mathbf{T_{6CSE}}$ $\mathbf{T_{6SFE}}$	20	6

SFE=Supercritical Fluid Extract	CSE=Conventional Solvent Extract
T_{SFE1}=Matodextrin:gelatin (15:2)	T_{CSE1}= Matodextrin:gelatin (15:2)
T_{SFE2}= Matodextrin:gelatin (15:4)	T_{CSE2}= Matodextrin:gelatin (15:4)
T_{SFE3}= Matodextrin:gelatin (15:6)	T_{CSE3}= Matodextrin:gelatin (15:6)
T_{SFE4}= Matodextrin:gelatin (20:2)	T_{CSE4}= Matodextrin:gelatin (20:2)
T_{SFE5}= Matodextrin:gelatin (20:4)	T_{CSE5}= Matodextrin:gelatin (20:4)
T_{SFE6}= Matodextrin:gelatin (20:6)	T_{CSE6}= Matodextrin:gelatin (20:6)

***In Vitro* Solubility**

The water solubility of microencapsulated curcumin was assessed by gently mixing in water (0.5%) whilst time for complete solubilization of each treatment was constant. In vitro solubility was mentioned as mg/mL.

CONCLUSIONS/RESULTS

The water solubility of microencapsulated curcumin was assessed by gently mixing in water (0.5%) whilst time for complete

Encapsulation Efficiency

The statistical data (Table **2**) expounded significant impact of treatments (wall material) on encapsulation efficiency of curcumin. Statistical analysis for the effect of various ratios of wall material (maltodextrin and gelatin) on encapsulation efficiency of curcumin extracted under supercritical condition (Table **15**) illuminated highest value (73.58±3.16%) for TSFE6 obtained using maltodextrin and gelatin at ratio of 20:6 trailed by T_{SFE3}, T_{SFE5}, T_{SFE2}, T_{SFE4} and T_{SFE1} as 71.39±2.21, 65.23±2.73, 62.84±2.32, 59.42±2.07 and 57.75±1.96% employing encapsulating wall material (maltodextrin and gelatin) at concentration of 10:6, 20:4, 10:4, 20:2 and 10:2, respectively. Amongst conventionally obtained extracts, the observed values for curcumin encapsulation was 69.32±2.83 (T_{CSE6}), 62.54±2.72 (T_{CSE3}), 61.85±2.42 (T_{CSE5}), 55.37±2.39 (T_{CSE2}), 54.91±1.86 (T_{CSE4}) and 48.29±1.73% (T_{CSE1}).

The current findings are in collaboration with Malacrida and Telis (2011), evaluated effect of different combinations of gelatin (0.5, 0.9, 1.8, 2.6, 3 and 6%) and maltodextrin (12, 18, 19, 20.6, 24.4, 28.1 and 29.7%) on encapsulation efficiency of curcumin. They noticed variations in this trait from 50.8 to 81.1%. Accordingly, maximum core retention was observed up to 81.1±0.3% by using emulsions containing 18% maltodextrin and 6% gelatin as wall material. On the other hand, formulations containing higher amount of maltodextrin rapidly hydrate within 5 min of agitation whereas, increased gelatin content lowered the solubility of curcumin microcapsules. It was analyzed that increase in maltodextrin did not affect appreciably curcumin retention due to low emulsification capacity. The encapsulation power was dependant on gelatin content. During emulsification, gelatin reduces interfacial surface tension as well as rate of coalescence.

Currently, Delfiya *et al*. (2015) elaborated influence of different contents of guar arabic and maltodextrin (from 0:100 to 100:0) as coating matrix on encapsulation power of turmeric oleoresins. They assessed that encapsulation efficiency improves by increasing concentration of gum arabic in microemulsion due to its more viscosity that enrobes microparticles and prevents coalescence. Likewise, Cano-Higuita and his fellows (2015) investigated the effect of different coating materials; gum arabic, mixture of modified starch & maltodextrin and mixture of gum arabic, modified starch & maltodextrin as well as drying methods; freeze and spray drying on retention capacity of curcumin. It was concluded that encapsulation efficiency significantly varied from 8 to 46% with the highest value 45.23% recorded for binary mixture of guar gum and modified starch at ratio of 50:50. Actually, curcumin is hydrophobic in nature and has ability to anchor polysaccharide chain. The resultant hydrophilic molecules restrain chain to aggregate thus providing more stability to lipophilic molecule. Similarly, hydrophilic coating of curcumin significantly confers high dissolution power to this active ingredient.

***In Vitro* Solubility**

It showed that solubility of microencapsulated nutraceutical SFE & microencapsulated nutraceutical CSE changed significantly with variations in concentration of maltodextrin and gelatin (Table **2**). Means for this trait (Table **17**) ranged from 4.37±0.23 to 3.85±0.15, 2.46±0.08, 2.27±0.11, 1.38±0.05 and 0.62±0.02 mg/mL for T_{SFE6}, T_{SFE5}, T_{SFE3}, T_{SFE4}, T_{SFE2} and T_{SFE1}, respectively. However, for conventionally extracted

microencapsulated curcumin, recorded values were 0.27±0.01 (T_{CSE1}), 1.14±0.04 (T_{CSE2}), 2.39±0.10 (T_{CSE3}), 2.11±0.07 (T_{CSE4}), 3.45±0.14 (T_{CSE5}) and 4.26±0.19 (T_{CSE6}) mg/mL.

The instant outcomes are in synchronization with the findings of, Carvalho *et al*. (2015) evaluated the differences in solubility of free and nanosuspension of curcumin. During solubility, curcumin nanoemulsion was more soluble in comparison to unformulated curcumin. Accordingly, smaller the particle size more will be the contact surface for hydrating solvent. One of the peers, Cano-Higuita *et al*. (2015) affirmed the improvement in water solubility of curcumin up to 97.88% using various combinations of maltodextrin, gum arabic and modified starch. Earlier, Wang *et al*. (2009) reported that curcumin enrobed into porous starch and gelatin gets solubilized after 4 min while free curcumin powder does not resolve at room temperature.

According to instant findings, encapsulation efficiency and water solubility increased with content of gelatin in microemulsion due to better film forming capacity in comparison to maltodextrin.

Treatments	**Encapsulation Efficiency (EE%)**	**Solubility (mg/mL)**
Microencapsulated Curcumin$_{SFE}$		
T_{SFE1}	57.75±1.96c	0.62±0.02c
T_{SFE2}	62.84±2.32bc	1.38±0.05bc
T_{SFE3}	71.39±2.21ab	2.46±0.08b
T_{SFE4}	59.42±2.07c	2.27±0.11b
T_{SFE5}	65.23±2.73b	3.85±0.15ab
T_{SFE6}	73.58±3.16a	4.37±0.23a
Microencapsulated Curcumin$_{CSE}$		
T_{CSE1}	48.29±1.73c	0.27±0.01c
T_{CSE2}	55.37±2.39b	1.14±0.04bc
T_{CSE3}	62.54±2.72ab	2.39±0.10b
T_{CSE4}	54.91±1.86b	2.11±0.07b
T_{CSE5}	61.85±2.42ab	3.45±0.14ab
T_{CSE6}	69.32±2.83a	4.26±0.19a

SFE=Supercritical Fluid Extract	**CSE=Conventional Solvent Extract**
T_{SFE1}=Matodextrin:gelatin (15:2)	TCSE1= Matodextrin:gelatin (15:2)
T_{SFE2}= Matodextrin:gelatin (15:4)	TCSE2= Matodextrin:gelatin (15:4)
T_{SFE3}= Matodextrin:gelatin (15:6)	TCSE3= Matodextrin:gelatin (15:6)

T_{SFE4}= Matodextrin:gelatin (20:2)	TCSE4= Matodextrin:gelatin (20:2)
T_{SFE5}= Matodextrin:gelatin (20:4)	TCSE5= Matodextrin:gelatin (20:4)
T_{SFE6}= Matodextrin:gelatin (20:6)	TCSE6= Matodextrin:gelatin (20:6)

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