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Enhancing antioxidant property of instant coffee by microencapsulation via spray drying

Sakawulan, D. [a]; Archer, R.[b]; Borompichaichartkul, C.[a*]

[a] Department of Food Technology, Faculty of Science, Chulalongkorn University, Phayathai Road, Patumwan, Bangkok 10330, Thailand.

[b] Massey Institute of Food Science and Technology, Massey University, Palmerston North 4442, New Zealand.

*E-mail of the corresponding author: chaleedab@hotmail.com, chaleeda.b@chula.ac.th

Abstract

This study is aimed to improve the antioxidant property of instant coffee by using microencapsulation technique and spray drying. Concentrated coffee extract was mixed with Konjac glucomannan hydrolysate (KGMH) and Maltodextrin (MD). The mixture of coating material and coffee extract was then spray dried at 160 - 180 °C inlet air temperature and at 85-90 °C outlet air temperature. KGMH can preserve retention of phenolic compounds, DPPH scavenging activity and antioxidant activity of FRAP (p<0.05 of instrant coffee better than other treatment.

Keywords: *Hydrolysed Konjac Glucomannan; Spray Drying; Microencapsulation; Instant Coffee, Antioxidant*

1. Introduction

Coffee brews as one of the most popular beverages in the world has extensively studied for health concern. Moreover, many people choose coffee as their daily drink due to its effect to body health. Coffee brews are accepted as a rich source of compounds possessing antioxidant and radical scavenging activities. Coffee is high in phenolic compounds, especially chlorogenic acids and their degradation products such as caffeic, ferulic and coumaric acids, polyphenols, trigonelline and alkaloids including caffeine and also high amount of melanoidins which exhibit significant antioxidant activities [1, 2].

Comparing antioxidant capacity in one cup from different form of coffees, instant coffee accounted for the highest amount of essential substances which expressed antioxidant capacity that 3-4 times higher than ground coffee. During the manufacturing of instant coffee, antioxidant and other essential compounds are concentrated which resulted in enhancing of antioxidant capacity compare to roasted bean powder [3].

More advantages of instant coffee stimulate the research more deeply in its production. The conventional processes of instant coffee are spray drying and freeze drying, both techniques have some limitations regarding energy consumption and final product qualities. Freeze drying produces the best product quality in term of aroma recovery, but it uses high energy and time that affected the production cost. While, spray drying leads the high production capacity at low investment, but engender higher thermal impact and resulted in decreasing of essential compounds such as natural antioxidants. In fact, that spray drying is the most applicable process in instant coffee industry yet gives lower antioxidant and flavor compounds than other processing, thereupon considering other techniques to lowering thermal impact is proposed.

Microencapsulation offered as a solution to reduce the core reactivity from essential compounds with the environmental factor. Konjac glucomannan (KGM) is neutral polysaccharides with mannose residues as predominant monomer and glucose as secondary sugar. The deep exploitation of KGM and its derivatives has been paid considerable attention in recent year. What is more, KGM in form of flour and hydrolysate can be conveniently used to wider application in some fields such as food science, pharmaceutical science, chemistry and biotechnology [4]. One of the latest experiments that has been deeply studied is investigation of hydrolyzed KGM on spray drying microencapsulation. Previous study have shown that hydrolyzed KGM (KGMH) worked as wall material by spray drying technique in antimicrobial powder, flavor encapsulated powder and nutraceutical powder [5, 6, 7]. Therefore, the aims of this study were to investigate the utilization of hydrolyzed KGM on encapsulation efficiency and to obtain the suitable spray drying condition in the production of high antioxidant instant coffee microencapsulation.

2. Materials and Methods

2.1 Materials

Medium dark/roast of Arabica roasted was provided by. Mannanase 50,000,000 IU per gram enzyme, food grade (Bosar Biotechnology, China) was used. Maltodextrin (MD) DE 10-15 (Food grade) was purchased from Chemipan (Bangkok, Thailand).

2.2 Methods

2.2.1 Coffee extract and coffee solution preparation for spray drying

Fine ground Arabica coffee (Green Net SE Co., Ltd, Bangkok, Thailand) (24 g) and 115 ml hot water are used in coffee extraction by using Moka Pot 22.5 x 10 cm (YAMI® YM-6007, China). Then coffee extract was evaporated by vacuum rotary evaporator (BÜCHI R-114, BÜCHI Labortechnik AG, Flawil, Switzerland) to get 10 °Brix of total solid. After that KGM hydrolysis is prepared by using Mannanase with 125 units per gram KGM is used for hydrolysis reaction. Modification method from previous study [6] was used to conduct KGM hydrolysis. All KGM hydrolysis was conducted under a controlled condition at 40±1 °C and 200 rpm of an overhead stirrer for 1 hour. Then KGMH solution was added by MD powder to adjust wall material concentration at 20% (w/w). For instance, 5% MD was added to 15% KGMH solution. Moreover, 20% KGMH was not added by MD, while 20 % MD solution (w/w) was used as control. Arabica coffee extract and wall material at ratio 2.2:1 (w/w) was mixed to obtain total solid mixture at 15% (w/w). Mixing process was done by magnetic stirrer for 5 minutes of stirring.

2.2.2 Spray drying

Drying experiment was done in a co-current Mini Spray Dryer (BÜCHI B-290, BÜCHI Labortechnik AG, Flawil, Switzerland). with inlet temperature at 160-180 °C and outlet temperature at 85-90 °C by adjusting flow rate.

2.2.3 Antioxidant properties analysis

Total phenolic compounds (TPC) was performed by Folin-Ciocalteu and calculated using gallic acid equivalent (CGA) [2]. Antioxidant activity was examined by DPPH scavenging ability method at 515 nm of spectrophotometric analysis [3]. Moreover, Ferric Reducing Antioxidant Power (FRAP) also used to examined antioxidant activity [2]. The FRAP measurement was done by spectrophotometry at 595 nm. Amount of chlorogenic acid was observed by using HPLC (Varian Prostar, USA) and the spectra were detected by Prostar 335 Photodiode Array Detector at 278 nm.

3. RESULTS AND DISCUSSION

3.1 Antioxidant Property

Fig. 1 presented antioxidant activity and amount of phenolic compounds and chlorogenic acid based on coffee solid in coffee extract and instant coffee powder. The results have shown that spray drying microencapsulation process, especially when using KGMH as wall material, was able to shield phenolic and antioxidant compounds.

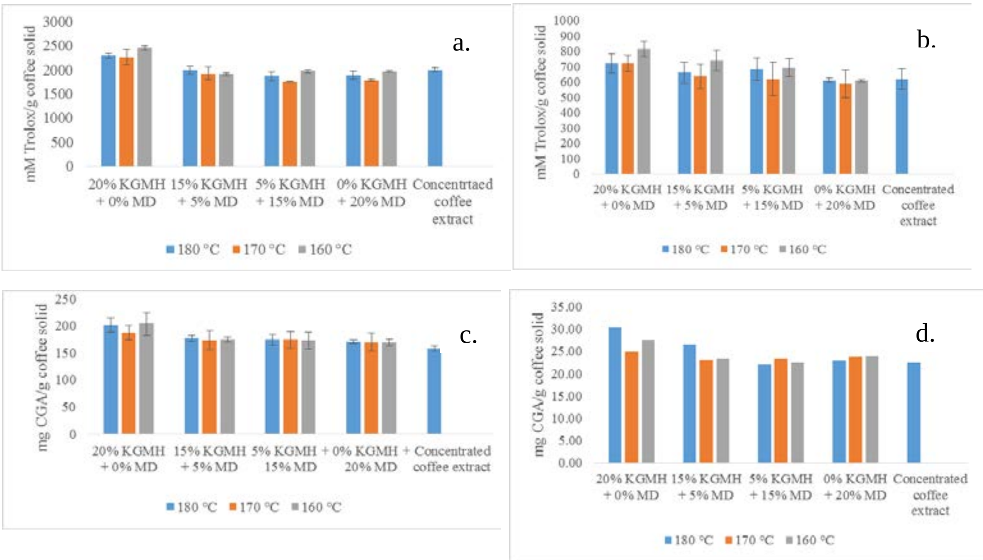

Fig. 1 Antioxidant activity of instant coffee measured by (a) DPPH (b) FRAP (c) total phenolic content (d) chlorogenic acid

In TPC measurement (Fig. 1c), the highest phenolic content in instant coffee powder was the formulation of 20% (w/w) KGMH at 160 °C with 204.04±20.98 mg CGA/g coffee solid (*p*<0.05), while the coffee extract presented 157.87±4.95 mg CGA/g coffee solid. To confirm TPC result, a specific phenolic compound which is chlorogenic acid (Fig. 1d) was observed by HPLC. In the current study, amount of chlorogenic acid in concentrated coffee extract had 22.49±1.35 mg/g coffee solid, while instant coffee powder contained 22-30.60 mg/g coffee solid. Among the treated instant coffee powders, 20% (w/w) KGMH instant coffee powder produced at 180 °C presented the highest content. In general, increasing KGMH concentration and inlet temperature lead to the higher chlorogenic acid content. On the other hands, DPPH scavenging ability results (Fig. 1b) have shown a similar pattern with TPC experiment where the highest value was exhibited by 160 °C spray dried of 20% (w/w) KGMH instant coffee powder (813.30±100.89 mM Trolox/g coffee solid) (*p*<0.05), while the extract presented 619.21±130.91 mM Trolox/g coffee solid. During spray drying, high temperature might trigger some reactions such as phenolic degradation and Maillard reaction which can create new compounds that possess higher antioxidant capacity. It is noted that in coffee mixture, antioxidant activity is contributed by phenolic compounds and melanoidins (non-phenolic). Since DPPH method has a wide range of mechanism, the new compounds created during drying could possibly be detected and express antioxidant capacity. Furthermore, in FRAP method (Fig. 1a), the similar formulation in TPC and DPPH methods was noted to have the highest value which accounted for 2,453.23±122.50 mM Trolox/g coffee solid (*p*<0.05).

3.2 Physical properties

The effects of spray drying conditions and wall material solutions on physical properties of microencapsulated instant coffee were observed including moisture content, water activity, water solubility index (WSI), water absorption index (WAI) and surface morphology shown in Table 1. The results pointed out that increasing KGMH concentration while decreasing MD concentration was tending to produce a lower yield. The increasing of inlet temperature was contributed to better production yield but it was inconsistent. The highest yield was produced by wall material of 20% (w/w) MD at 160 and 180 °C of inlet temperature (*p*<0.05) which accounted for 65.27%±4.67 and 64.00%±8.03. In all inlet temperature, 20% (w/w) KGMH alone was exhibited comparable results with the mixture of KGMH and MD as wall materials. This result was in line with Tolun *et al*. (2016) [8] which have a similar wall material design with current study and concluded that MD (DE 17-20) alone produced the highest yield at 52.77%, while when MD was mixed with gum Arabic the results had a contrary influence on the yield. During spray drying, instant coffee with KGMH was had more loses because of KGMH properties. KGMH solution is stickier than MD solution, therefore, the amount of adhered sample in drying chamber after drying was found higher in KGMH instant coffee sample.

Table 1. Product yield, moisture content, and water activity of instant coffee

Inlet temperature (°C)	Wall material	Product yield (%)	Moisture content (% w.b.)^{ns}	Water activity^{ns}
160	20% (w/w) KGMH	53.66±4.81^{a}	3.73±0.52	0.24±0.02
	15% (w/w) KGMH + 5% (w/w) MD	52.54±1.88^{a}	3.42±0.34	0.22±0.05
	5% (w/w) KGMH + 15% (w/w) MD	61.39±2.65^{bcd}	3.75±0.09	0.23±0.00
	20% (w/w) MD	65.27±4.67^{d}	3.64±0.53	0.23±0.02
170	20% (w/w) KGMH	54.30±0.15^{ab}	3.52±0.36	0.21±0.01
	15% (w/w) KGMH + 5% (w/w) MD	53.07±1.77^{a}	3.66±0.22	0.23±0.01
	5% (w/w) KGMH + 15% (w/w) MD	58.31±3.10^{abcd}	3.72±0.04	0.23±0.02
	20% (w/w) MD	62.26±6.31^{cd}	3.58±0.28	0.22±0.03
180	20% (w/w) KGMH	55.27±2.37^{abc}	3.37±0.29	0.25±0.03
	15% (w/w) KGMH + 5% (w/w) MD	53.24±2.91^{a}	3.68±0.30	0.25±0.03
	5% (w/w) KGMH + 15% (w/w) MD	61.39±2.65^{bcd}	3.40±0.23	0.24±0.01
	20% (w/w) MD	64.00±8.03^{d}	3.54±0.10	0.24±0.01

Values in a column followed by different letters are significantly different (p<0.05)

ns: non-significant

WSI is an important property to repeal powder behavior in aqueous and its reconstitution ability**.** Table 2. presented the WSI of microencapsulated instant coffee powder from different spray drying condition and formulation. In general, the value of WSI was in contrary to the amount of KGMH used but correlated with increasing of inlet temperature. The most solubilize powder was come from instant coffee produced from 20% (w/w) MD at 180 °C (98.98±0.87%) while the lowest WSI was 20% (w/w) KGMH powder at inlet temperature 170 and 160 °C (89.03±3.68 and 88.95±5.16%) (p<0.05). Similar finding from Jafari *et al.* (2017) [9] who found that juice powder with 25-45% (w/w) MD as drying aids have WSI above 90%, while Adamiec *et al.* (2012) [5] noted that by using combination KGMH and gum Arabic at wall material concentration at 9% (w/w) presented WSI at 67-69%. Even though KGMH instant coffee exhibited the lowest WSI, the value of WSI was still above 88% which mean that all instant coffee powder still have a good solubility.

Table 2. Water solubility index (WSI) and water absorption index (WAI) of instant coffee

Inlet temperature °C	Wall material	WSI (%)	WAI (%)
160	20% (w/w) KGMH	88.95±5.16^{a}	8.94±1.51^{c}
	15% (w/w) KGMH	91.89±4.10^{abc}	3.07±0.76^{a}
	5% (w/w) KGMH	96.54±0.88^{cd}	3.13±1.36^{a}
	20% (w/w) MD	94.08±3.57^{cd}	3.20±0.72^{a}
170	20% (w/w) KGMH	89.03±3.68^{a}	9.01±1.54^{c}
	15% (w/w) KGMH	91.90±3.06^{abc}	4.59±1.49^{ab}
	5% (w/w) KGMH	96.00±0.79^{bcd}	3.83±1.60^{ab}
	20% (w/w) MD	96.80±2.34^{cd}	3.27±1.33^{a}
180	20% (w/w) KGMH	89.38±3.61^{a}	8.80±1.89^{c}
	15% (w/w) KGMH	90.35±3.54^{abc}	5.91±1.19^{b}
	5% (w/w) KGMH	92.47±5.78^{abcd}	5.41±0.64^{ab}
	20% (w/w) MD	98.98±0.87^{d}	3.58±0.73^{ab}

Values in a column followed by different letters are significantly different (p<0.05)

4. CONCLUSIONS

Antioxidant property of instant coffee can be enhanced by microencapsulation using KGMH as an appropriate natural wall material. KGMH concentration affected antioxidant and other physicochemical properties. Increasing KGMH concentration leads to the better antioxidant properties including TPC, antioxidant capacity by DPPH and FRAP and chlorogenic acid content. The wall material was able to shield almost all antioxidant component and resulted in the excessive retention percentage. The application of KGMH alone as wall material exhibited the best retention percentage compare to microcapsule made from KGMH-MD in all ratio and MD alone. The inlet temperature of spray drying was showing an important role in antioxidant properties. The increasing of inlet temperature was correlated with lower retention of antioxidant properties except for chlorogenic acid that was increased. In general, the lowest inlet temperature (160 °C) produced better overall antioxidant properties than spray drying at 170 and 180 °C. The best condition of producing instant coffee from this study is 20% (w/w) KGMH as wall material at 160 °C inlet temperature of spray drying.

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