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## Bioavailability, Stability and Antioxidant Activity of Ginger and Curcumin Before and After Encapsulation

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## ABSTRACT



Ginger (Zingiber officinale) and Curcumin (Curcuma longa L) have been used in folk medicine due to their high content of bioactive components. The stability of these bioactive components is one of the important limiting factors for their utilization. In this study, encapsulation of the bioactive components of ginger and curcumin extracts with maltodextrin or ßcyclodextrin by Freeze-dryer was applied to improve the stability and properties of these components. Solubility of C-MD and G-MD was increased to 83.68% and 95.97% respectively, compared with curcumin extract and ginger extract 17.96% and 28.14%, respectively. The results showed enhancement of total phenol content in G-CD 49.81 mg/100 g DM, while in ginger extract was 43.61mg /100 g DM. The bioavailability of encapsulated plant extracts improved by calculating the retained activity % of reducing power: which was 110.2%, 111.8 % and 121.5% for G-CD, G-MD, and C-MD respectively. The stability of the encapsulated plant extracts was studied by measuring the thermal stability and change in pH. The encapsulation of ginger extract with both CD and MD increased the stability of ginger in acidic pH5 and curcumin stability against neutral and alkaline pH. The results showed an increase in the thermal stability of encapsulated plant extracts compared to the studied plant extracts. In G-CD, the total phenols reduced from 49.8mg/100 g DM to 32.8mg/100 g DM, after in-vitro gastric digestion. Encapsulation of ginger and curcumin extracts led to an improvement in solubility, thermal stability, pH stability and bioavailability of bioactive components.

Keywords: Ginger, Curcumin, Encapsulation, Stability and Bioavailability.

## INTRODUCTION

Several plant extracts, herb and spice extracts are considered beneficial for human health, studies tend to produce and use plant extracts due to their high content of important phytochemical compounds and bioactive compounds, certain natural bioactive ingredients in it are useful as preventive medicines against some diseases such as chest diseases, infections, heart diseases and different types of cancer. For these reasons, various plant extracts are considered to have an important role as therapeutic agent (Al Jumayi *et al.*, 2022).

Food plant sources contain many important bioactive compounds that have many health benefits, but their utilization depends on their stability, sensitivity to many external factors such as heat, change in acidity values, etc., which affects their bioavailability in the human body, biological accessibility, and therefore the bioavailability of those compounds depends greatly on the structure and form in which they are introduced into the organism.(Grgić *et al.*, 2020).

Turmeric rhizome (Curcumin) is a perennial herb *Curcuma longa L.* Curcumin which is in the family Zingiberaceae, which is a crystalline polyphenol low molecular weight, yellow that is widely cultivated in tropical and subtropical regions. The use of turmeric has expanded as a food ingredient because it is flavouring, and food colouring agent, in addition to containing several bioactive compounds such as (curcumin [1,7- bis(4-hydroxy-3-methoxyphenyl)-1,6-heptadiene-3,5-dione], consist of three main active

components: curcumin, desmethoxycurcumin and bisdemethoxycurcumin) that are antioxidants and therapeutic agents and medicaments in different diseases. Curcumin has various pharmacological effects including antibacterial, anti-inflammatory, hepatoprotective, anti-tumour and anti-viral activities. The bioavailability of curcumin's bioactive compounds is reduced by its low water solubility rate (Sahne *et al.*, 2016).

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Ginger (*Zingiber officinale*) is one of the most used plant sources as a spice and in folk medicine and have a long history as of being used as a medicine, as it contains many active compounds and volatile oils. The most important of these compounds are 6-, 8-, 10-gingerols, which are responsible for the pungent taste that turns into 6, 8, 10 shogaols by heating, in addition to containing many compounds of phenols and flavonoids and many important elements such as calcium, iron and magnesium, which raise the nutritional value of it. Studies have stated that these compounds have an important role in reducing the incidence of blood clots and reducing blood cholesterol and triglycerides.(G. M. Khiralla, 2015; Shahrajabian *et al.*, 2019).

Recent studies tend to use advanced techniques to protect the active biological compounds in plant extracts to increase the biological utilization rate for them. In-vitro gastro digestion is one of the most important laboratory tests used to identify the extent of bioavailability of phenolic compounds during the digestion process due to the complexity of the mechanisms through which phenolic compounds operate in living organisms. The encapsulation process is one of the most important methods of protecting the bioactive compounds, which is done in many ways, such as freezedrying, spray-dryer, etc. The encapsulation process is an influential factor on the bioavailability of the active compounds, as it depends on ensures the coating on the bio active compound and releasing it in the target place to benefit from it inside the digestive tract.(Tumbas Šaponjac *et al.*, 2020).

Encapsulation of active vital compounds is a means of preserving these compounds and increasing their stability, and a good selection of the packaging material is one of the most important foundations for the success of the encapsulation process. Recent research has used many carriers such as oligosaccharides, starch, arabic gum and dextrin's etc.(Bin, 2022).

This study was designed to investigate the encapsulation of bioactive compounds in food plant extracts, track the stability and bioavailability of these compounds, and compare the stability of these bioactive compounds after and before encapsulation under different stresses.

## MATERIALS AND METHODS

Ginger (Zingiber officinale) and Curcumin (Curcuma longa L) were obtained from local market Cairo City, Egypt.

Chemicals and Reagents: sodium chloride, sodium carbonate, sodium hydroxide, sodium nitrate, aluminum chloride, potassium ferricyanide, tri-chloroacetic acid, and also all the used solvents Hexane, acetone, ethanol, methanol were reagent purchased from Al- Nasr co. 2,2-diphenyl-2-picrylhydrazyl radical (DPPH), , Folin-Ciocalteus (phenol reagent), , gallic acid, quercetin, maltodextrin, and  $\beta$ -Cyclodextrin were obtained from Sigma, Chemicals Company.

#### **Preparation of extracts**

The *Zingiber officinale* rhizomes were cut into slices and oven dried at 50°C for 72 hours. Then 10 g of dried and grinded sample was taken and defatted with hexane according to (Andriyani *et al.*, 2015). After that, the sample was filtrated throw filter paper and stored in dark glass. (Popuri pagala, 2013).

Dried turmeric rhizomes were grounded into fine powder by using electrical grinder (IKA WERKE), then about 100 gm of the powder were defatted with hexane for removing volatile oils. The residue was left to dry and retreated with acetone as a suitable solvent for extraction of curcumin. This process was repeated three times. The ratio of powder to acetone was 1:3 w/v as described by (Popuri pagala, 2013).

#### Encapsulation of plant extracts by Freeze Drying

#### Preparation of inclusion complexes of plant extracts with β-Cyclodextrin (CD)

(Marcolino *et al.*, 2011) described the formation method of CD/guest complexes with two plant extracts as follows, an aqueous solution of 0.06 mol/L was prepared. About 50ml of the prepared ethanolic extract of ginger and 50 ml of the prepared acetone extract of curcumin were individually added drop wise to 50 ml of the CD aqueous solution with continuous stirring for 24 h at room temperature. After that, the mixture was stored overnight at 4<sup>o</sup>C then freeze dried by " ZiRBUS VaCo5 " device. Finally, the obtained

lyophilized powders were packed in polyethylene bags and stored at 4<sup>o</sup>C in the dark until the start of the analysis.

## Preparation of inclusion complexes of plant extracts with Maltodextrin (MD)

The formation of MD complexes with both plant extracts was carried out according to (Narayanan *et al.*, 2018),(Yamashita *et al.*, 2017). MD was added to each concentrated extract to obtain 30 % total solids concentration, followed by stirring to obtained homogenized samples for 24 hr. Both plant extracts mixtures were transferred to freeze dryer device and the obtained powder was packed in polyethylene bags and stored at 4°C till use.

#### Moisture content

The determination of moisture content of encapsulated plant extracts was done using an accurate preweighted samples and dried at  $105^{\circ}$ C /5 hr, with the calculation of moisture, which is the difference in weight after drying to before drying, in relation to the weight of the sample (AOAC, 2020).

#### Hygroscopicity

According to the methods described(Tonon *et al.*, 2008), the hygroscopicity of encapsulated plant extracts was evaluated with some modifications. A saturated NaCl solution was prepared and placed in a desiccator (75% relative humidity). The pre-weighed samples were kept for a week in a desiccator containing saturated NaCl solution and weighed after this period. Weight change was expressed by water absorption in grams per 100 g of dry samples.

#### Solubility

0.5 gm of the encapsulated plant samples were dissolved in 50 ml distilled water and stirred at room temperature for 30 min. as described by(Cano-Chauca *et al.*, 2005). Then all the suspensions were centrifuged at 1800 rpm for 15 min. using centrifuge model (Sigma 1-6p). 25 ml of the supernatant were transferred to a pre- weighted petri dishes and dried at 105  $^{\circ}$ C for 5 hr. The weight of soluble solids was used to calculate the solubility percentage.

## Total phenolic content

Total phenolic contents (TPC) in the prepared extracts was determined photo metrically using Thermo Scientific Evolution 300 UV/VIS Spectrophotometer according to the method described by(Radošević *et al.*, 2017) with some modifications.0.5 mL of sample ( plant extracts or encapsulated plant extracts)were added with the mixture of 0.5 mL of Folin-Ciocalteu reagent and 0.5 mL of saturated sodium carbonate solution and then the mixtures were incubated at 50°C for 5 min and cooled to room temperature. The absorbance was determined at 765 nm. A standard calibration curve of gallic acid within the range of 10-100 µg/ml was done for calculating the amount of TPC as mg G.A. E / 100 g dry matter.

#### Total flavonoid content

The method described by (Bhandari Kwak, 2015) was used for determination of TFC. Briefly, 1 ml of extract was added to 5 ml D.W in 15 ml falcon tube, then 300  $\mu$ l of 5 % sodium nitrate solution was added. The mixture was incubated for 5 min. then 600  $\mu$ l of AlCl3 (10 %) was added followed by adding 2 ml of 1 M NaOH. The volume was raised to 10 ml by D.W. The absorbance was measured at 510 nm. For calculating the TFC a standard calibration curve of quercetin within the range of 10 – 100  $\mu$ g/ml was used, and

TFC was expressed as mg of quercetin equivalent per 100 g dry matter.

#### Recovery index of bioactive components

(Olds *et al.*, 2011) described the determination method of bioavailability of bioactive component (BAC) by calculating the recovery index for each BAC (total phenols, total flavonoids) the recovery index was calculated as following:

#### Recovery index of BAC %=[(BAC after treatment/BAC before treatment)] X 100

#### where BAC before treatment and BAC after treatment are the content of each bioactive component before and after treatment respectively. Antioxidant potential

#### - DPPH radical-scavenging activity

By the method described by (Celep *et al.*, 2013) the determination method of free radical scavenging activity was done by adding 1 ml of freshly prepared DPPH (2,2 diphenyl-1-picrylhydrazyl) solution 0.1 mM in methanol was added to 0.1 mL different extract (or 0.1 mL distilled water in control), then the mixtures was mixed by vortexed and incubated in dark place for 30 min.After that,the absorbance was measured at 517 nm. The percentage of antiradical activity (ARA) against DPPH was calculated according to the following equation: -

#### ARA% =[ (Asi7 of control - Asi7 of sample) /Asi7 of control) X 100

#### - Reducing power (RP)

For the determination of Reducing power activity, the method described by (Jayaprakasha *et al.*, 2001) was applied. 2.5 mL of phosphate buffer (pH 6.6) and 2.5 mL potassium ferricyanide (1% w/v) were added to 0.1 mL different extracts and incubated at 50 °C for 30 min. then, (2.5 ml) trichloroacetic acid (10% w/v) was added to the mixture and centrifuged at 3000 rpm for 10 min. (2.5 mL) of Supernatant was diluted with (2.5 mL) of distilled water and shaken with 0.5 mL freshly prepared ferric chloride (0.1% w/v). Absorbance was measured at 700 nm.

#### Total antioxidant capacity

The method described by (Prieto *et al.*, 1999) was performed for determination of total antioxidant capacity (TAOC) of different samples. 0.3 ml of sample was mixed with 3 mL of reagent solution consisting of, 4 mM ammonium molybdate, 0.6 M sulfuric acid and 28 mM sodium phosphatemonobasic. The mixtures were incubated for 90 min at 95°C. At 695 nm the absorbance was measured. The total antioxidant capacities were expressed as mg ascorbic acid equivalent (AAE) per 1 mL sample.

## Retained activity (RA%)

Retained activity (RA%) of scavenging activity, reducing power and total antioxidant activity after treatment was calculated according to the method described by Khiralla and Ali (2020) as follows:

#### % Retained activity = (Activity after treatment/Activity of before treatment) X 100

#### In vitro digestion procedure: -

A simulation study of gastrointestinal digestion process was done according to the method described by (Cassani *et al.*, 2018) with some modifications. The simulation study included two phases; first phase was the simulated stomach solution which prepared as follows: 3 g/L pepsin, 7.30 g/L NaCl, , 0.52 g/L KCl, 3.78 g/L NaHCO3, was dissolved in distilled water, and the pH of the solution

was adjusted to 2 with 5 M HCl. 10 mL of sample solution was added to 10 mL simulated stomach solution, then incubation at 37 °C with shaking in water bath for 1.5 hr at 100 rpm. Then the mixture was immediately cooled in an ice bath. To begin the second phase (simulated intestinal digestion), 10 mL of simulated intestinal fluid (1.27 g/L NaCl, 0.23 g/L KCl, 0.64 g/L NaHCO3, 1 g/L pancreatin, 1.5 g/L bovine bile salts) was added to sample and the pH was adjusted at pH 8. The mixtures were incubated at 37°C for 3 h under shaking at 100 rpm. Samples were kept in an ice-bath for 10 min to stop intestinal digestion. The samples were then centrifuged at 3000 rpm for 20 min. The supernatants were collected and filtered using filter paper. Samples were stored at - 20 oC until required for further analysis. To measure the effect of the in-vitro gastro intestinal digestion process on the bioactive compounds, total phenols and radical scavenging% ability were measured before and after the simulated in-vitro gastro intestinal digestion to assay the bioavailability of the active biological compounds after digestion to determine the actual value of those compounds that are absorbed by the body after the process of intestinal digestion

#### Stability analysis

The effect of encapsulation of plant extract on the stability of the active bioactive compounds was measured by measuring the stability of the encapsulated plant extracts against changes in both thermal and pH.

## Thermal Analysis

Thermographs were conducted in (Micro Analytical Center, Faculty of Science, Cairo University) using Shimadzu DSC-60 instrument under nitrogen gas. The operation condition was: initial temperature, 10°C; final temperature, 400°C and heating rate 10°C min-l, and sample weight was about 2.0 mg in aluminum seal cell.(Fernandes *et al.*, 2013). **pH stress** 

Samples pH stability at various pH conditions were assessed according to the method described by (Meena *et al.*, 2013) with some modifications. The prepared samples were dissolved in different buffer solutions (pH 3, 5, 7, 9). The stability of ginger extract and ginger complexes with CD and MD was measured at 281.4 nm (ShindeSachin *et al.*, 2012), about curcumin extracts and its complexes with CD and MD was measured at 421nm (Hazra *et al.*, 2015)

#### Statistical analysis

All values were presented as the mean \_ standard deviation (S.D.) performed in triplicate and statistically analyzed using one way ANOVA (SAS 8.2, Cary, NC, USA).

#### **RESULTS AND DISCUSSION**

## Preparation and characterization of encapsulated plant extract

Both prepared plant extracts (Ginger & turmeric) were encapsulated by CD and MD and were examined to detect the presence of the major compound in it by using the spectrophotometer adjusted at the optimum wavelength 281.4 nm for gingerol, and 420 nm for curcumin. The formation of the encapsulated plants complexes was confirmed by spectroscopic analysis (UV-Vis.). (Archontaki *et al.*, 2002) and thermal analysis (DSC) (Zhang *et al.*, 2018a).

UV. -Vis. Spectra of ginger extract and encapsulated ginger extract with both CD and MD are presented in fig. (1). Both CD and MD showed no absorbance peaks but, ginger extract showed maximum absorbance at 280 nm while a shifting to 278 nm and 297 nm appeared respectively in G-CD and G-MD indicating the formation of ginger extract complex with both CD and MD (encapsulation process). Table (1)





Figure 1. UV-Vis absorption spectra of Ginger extract before and after encapsulation with CD or MD.

UV. -Vis. Spectra of Curcumin extract and encapsulated Curcumin extract with both CD and MD are presented in fig.(2).The maximum absorbance of curcumin extract appeared at 427nm but encapsulated C-CD and C-MD complexes showed a transition to 421 nm(Table1) indicating successful formation of the complex, this data was in agreement with (Archontaki *et al.*, 2002).



Figure 2. UV-vis absorption spectra of Curcumin before and after encapsulation with CD or MD.

Table 1. Wavelength of UV-spectra peaks before and after encapsulation of plant extract with βcvclodextrin or maltodextrin.

Diarré Carrosa	UV.Scan				
Plant Source	Extract	E-CD	E-MD		
Ginger	280 nm	278nm	297nm		
Curcumin	427nm	421nm	421nm		

E-CD =encapsulated extract with  $\beta$  -cyclodextrin, E-MD =encapsulated extract with maltodextrin.

#### Solubility:

Solubility of ginger extract and curcumin extract before and after encapsulation presented in Table (2). The data shows an improvement in the solubility of the plant extracts after encapsulation compared with before encapsulation, where it was 17.96% this in curcumin extract and it was increased to 83.68 % after encapsulation of Curcumin extract with MD. The same result was in ginger extract before and after encapsulation with MD, it was 28.14% and 95.97% respectively. The obtained results agreed with the resulted data by (da Silva *et al.*, 2021).

(Loron *et al.*, 2021), mentioned that the encapsulation process improves the solubility as a result of the displacement of the polar water molecules from the dextrin, the formation of a large number of hydrogen bonds that formed with the return of the displaced water resulting from the formation of the complex between plant extract component with carrier and the reduction of the reaction rate between the hydrophobic guest and the aqueous medium.

Table	2.	%	Solubilit	y bef	ore	and	after	encap	osulation	of
	p	lant	t extract v	vith f	3- cv	clod	extrin	or m	altodextr	in.

Diant Commo	Solubility%					
Plant Source	Extract	E-CD	E-MD			
Ginger	28.14	58.41	95.97			
Curcumin	17.96	20.84	83.68			

E-CD =encapsulated extract with  $\beta$  -cyclodextrin, E-MD =encapsulated extract with maltodextrin.

The hygroscopicity and moisture content of encapsulated plant extracts were presented in table (3). G-CD and G-MD showed similar values of moisture content 2.13 % and 3.66 % while hygroscopicity values were 4.87% and 11.84 % respectively. These results agreed with (Caparino *et al.*, 2012)who also reported similar results of freeze- dried mango powder. C-CD and C-MD presented hygroscopicity values and moisture content around the range of the recorded values as shown in table (3). A specific interaction between the wall material and active compounds is responsible of reducing hygroscopicity.(Labuschagne, 2018).

Table 3. Hygroscopicity and Moisture % after<br/>encapsulation of plant extract with β-<br/>cvclodextrin or maltodextrin

Diant Sauraa	Hygroscopici	ity (g/ 100g d.w)	Moist	ure %
Plant Source	E-CD	E-MD	E-CD	E-MD
Ginger	4.87	11.84	2.13	3.66
Curcumin	4.01	11.87	2.54	5.2
E-CD =encapsulated extract with β -cyclodextrin, E-MD =encapsulated				

extract with maltodextrin, d.w = dry weight.

#### **Bioactive Components**

Total phenolic content (TPC) and Total flavonoid content (TFC)

To characterize the prepared plant extracts (ginger and curcumin) and encapsulated plant extract with CD (E-CD) and MD (E-MD) by determining all of this total phenols, total flavonoids, antioxidant activity and bioavailability of bioactive in it.

The content of TPC and TFC before and after encapsulation was presented in table (4). Total phenol content in ginger extract was 43.61mg GAE /100 g DM, while in G-CD and G-MD was 49.81and 36.91 respectively. The decrease in G-MD of phenolic content may be due to the retention caused by complexation of ginger extract with MD, this data was according to(Kuck Noreña, 2016) and (Yamashita *et al.*, 2017).

The TFC in ginger extract was 25.64 mg QE /100 g DM, while it was in G-CD and G-MD; 22.5 and 31.85 respectively. In curcumin extract and encapsulated curcumin extract with both CD and MD; low content of TPC and TFC was found and it is also may due to the retention of bioactive component resulted by encapsulation process as described by (Kuck Noreña, 2016) and (Saokham *et al.*, 2018).

T.		T.Phenols mg GAE /100 g DM			T.Flavonoids mg QE /100 g DM		
Plant Source	Extract	E-CD	E-MD	Extract	E-CD	E-MD	
Ginger	43.61b±0.26	49.81a±1.5	36.91c±0.9	25.64b±0.44	22.5c±0.72	31.85a±0.98	
Curcumin	6176a±460	525.6c±30.9	662.5b±6.1	1009a±13.7	76.69c±1.5	86.63b±3.02	
E-CD =encapsula	ated extract with <b>B</b> -cv	clodextrin, E-MD =ei	ncapsulated extract v	vith maltodextrin. (	FAE =gallic acid equiv	valent. OE= quercetir	

Table 4. Total phenols and T.Flavonoids before and after encapsulation of plant extract with β- Cyclodextrin or maltodextrin.

E-CD =encapsulated extract with  $\beta$  -cyclodextrin, E-MD =encapsulated extract with maltodextrin, GAE =gallic acid equivalent, QE= quercetin equivalent, DM= dry mater, a,b,c =Mean values in the same row with different superscripts are significantly different (p < 0.05). Each value is expressed as mean  $\pm$  S.D (n = 5).

#### **Recovery index of TPC after encapsulation:**

The recovery index of both TPC and TFC of the prepared encapsulated plant extracts was presented in fig. (3) and fig (4). The figures showed an increase in the recovery index of TPC and TFC in G-CD and G-MD On the contrary in C-CD and C-MD. This may be due to the low availability of curcumin comparing with gingerol (E. I. Paramera *et al.*, 2011c).

The encapsulation process increased the bioavailability of encapsulated ginger extract and curcumin extract, this note which agreed with(López-Tobar *et al.*, 2012; E. Paramera *et al.*, 2011a; Wang *et al.*, 2009). Also, the obtained data was in accordance with(E. Paramera *et al.*, 2011a).



Figure 3. Recovery Index (%) of Total Phenols after Encapsulation plant sources.



Figure 4. Recovery Index (%) of Total Flavonoids after Encapsulation of plant sources.

#### Antioxidant activity

The antioxidant activity was determined by using multiple mechanisms including radical scavenging activity (%ARE), reducing power (RP) and total antioxidant capacity (TAOC) Radical scavenging activity (%ARE).

The %ARE values were recorded in table (5) for the encapsulated ginger and curcumin plant samples. Ginger extract and its encapsulated formula presented high free radical scavenging activity, especially G-CD 43.93 % and 38.01 % for G-MD, this may be due to the neutralization of

free radicals, either transfer of hydrogen atom or by transfer of an electron as described by (Naik *et al.*, 2003).

- Curcumin extract (C-E) and its encapsulated formula (C-CD and C-MD) exhibited high %ARE values; 50.11, 52.37 and 46.44 respectively. The antioxidant activity of curcumin is due to the ability of curcumin to bind free radical and to donate a hydrogen atom. Curcumin can neutralize free radicals by donating electrons which lead to create stable products.(Hewlings Kalman, 2017).

 
 Table 5. Radical scavenging activity before and after encapsulation of plant extract with βcyclodextrin or maltodextrin

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Diant Common	Radical scavenging activity %					
Plant Source	Extract	E-CD	E-MD			
Ginger	50.45 a±0.8	43.93b±0.6	38.01c±3.8			
Curcumin	50.11a±2.6	52.37a±2.5	46.44b±3.1			
E-CD =encapsulated extract with β -cyclodextrin, E-MD =encapsulate extract with maltodextrin, a,b,c =Mean values in the same row with different superscripts are significantly different ( $p < 0.05$ ). Each value is expressed as mean + S,D ( $n = 5$ ).						

The retained activity of the radical scavenging activity after encapsulation was presented in fig. (5). The data exhibits an increase of the retained activity of all the encapsulated samples. The role of encapsulation to enhance the antioxidant activity was investigated by (Lindsey *et al.*, 2003). Briefly, encapsulated plant extract with CD has a protective effect against peroxidation because the ability to chelation of the inducer ion and also as a result of increasing solubility.



Figure 5. Retained activity % of Radical scavenging activity %after Encapsulation plant

## Reducing power activity and Total antioxidant capacity (TAOC)

The role of encapsulation of the prepared plant extracts on its reducing power activity and TAOC was declared in table 6. Significant increase in RP for each of G-CD and G-MD, it was 1.025 µg/ml as Ascorbic Acid and 1.04 µg/ml as Ascorbic Acid respectively, compared with ginger extract where it was 0.93 µg/ml as Ascorbic Acid. (Tupuna *et al.*, 2018) mentioned that maltodextrin has protected the core material by acting as a barrier towards oxygen. In additional, maltodextrin prevent core material to transform into unstable form (Khalifa *et al.*, 2019).

Table 6. Reducing Power and Total Antioxidant Capacity before and after encapsulation of plant extract with βcyclodextrin or maltodextrin.

Diant Course	Reducing I	Reducing Power (µg/ml as Ascorbic Acid)			TAOC (µg/ml as Ascorbic Acid)		
Flant Source	Extract	E-CD	E-MD	Extract	E-CD	E-MD	
Ginger	0.93b±0.05	1.025a±0.02	1.04a±0.02	37.09a±2.67	34.72b±0.76	36.8a±0.95	
Curcumin	2.89b±0.1	2.95b±0.07	3.51a±0.07	35.71a±1.47	35.32a±1.02	29.36b±1.36	

E-CD =encapsulated extract with  $\beta$ -cyclodextrin, E-MD =encapsulated extract with maltodextrin, TAOC = total antioxidant capacity .a,b =Mean values in the same row with different superscripts are significantly different (p < 0.05). Each value is expressed as mean  $\pm$  S.D (n = 5).

The retained activity of both (RP) and (TAOC) are presented in fig. (6) and fig. (7) respectively. The encapsulation of ginger extract and curcumin extract with both CD and MD caused a high retained activity of RP and TOAC as shown in figures 3 and 4.



Figure 6. Retained activity (%) of Reducing Power after Encapsulation of plant sources.



Figure 7. Retained activity (%) of Total Antioxidant Capacity after Encapsulation of plant sources.

#### pH stability:

Table (7) shows the degradation rate of ginger extract before and after encapsulation with both CD and MD at varying pH levels. The data revealed that acidic condition increases gingerol degradation. This result is like the result obtained by (Bhattarai *et al.*, 2001) who reported that the main cause of gingerols sensitivity in acidic condition is  $\beta$ hydroxy keto group which undergoes catalytic dehydration as presented in fig 8. On the other hand, the process of encapsulation of ginger extract with both CD and MD increased the stability of ginger in acidic condition pH5.

Table 7. % Degradation of Ginger extract before and after encapsulation with ß- cyclodextrin or maltodextrin on different pH values.

	ianouczu n	i on unici	chi phi va	manouextrin on unterent pri values.					
Time	Commle	Degradation %							
Time	Sample	pH3	pH5	pH7	pH9				
	GE	91.9	61.18	6.7	4.25				
Zero Time	G-CD	32.35	4.69	7.88	9.15				
	G-MD	21.07	15.78	9.45	9.66				
	GE	34.4	96.77	8	6.69				
1 hr	G-CD	57.27	15.88	5.22	1.21				
	G-MD	6.62	7.52	8.92	10.81				
2 hr	GE	18.79	93.45	8.1	4.7				
	G-CD	60.94	22.2	1.97	1.33				
	G-MD	1.54	4.39	9.28	8.16				
3 hr	GE	10.75	91.56	8.2	3.79				
	G-CD	62.38	21.88	2.5	4.35				
	G-MD	1.47	1 54	911	5 59				

 $\overline{\text{GE}}$ = ginger extract, G-CD =encapsulated ginger extract with  $\beta$  -cyclodextrin, G-MD =encapsulated ginger extract with maltodextrin.



Figure 8. Schematic degradation process of gingerol in aqueous acidic environment (Bhattarai *et al.*, 2001).

Curcumin is a sensitive compound to high pH condition as concluded from the reported data in table (8). The obtained result is similar to the conclusion by (Kumavat *et al.*, 2013) who declared that curcumin is sensitive to pH 7 and alkaline pH, but is stable at high acidic pH. In additional the improvement in curcumin stability against pH by encapsulation is similar to the obtained result in our result.

Table 8. % Degradation of Curcumin extract before and after encapsulation with β- cyclodextrin or maltodextrin on different pH values.

Time	Comple		Degrad	lation %	
Time	Sample	pH3	pH5	pH7	pH9
	CE	3.33	23.59	15.68	28.7
Zero Time	C-CD	3.2	19.16	3.09	3.29
	C-MD	3	1.09	2.9	1.8
	CE	3.33	35.42	16.18	40.68
1 hr	C-CD	3.4	28.97	4.5	12.07
	C-MD	3.3	20.51	5.7	7.35
	CE	4.5	39.7	17.28	46.02
2 hr	C-CD	4.6	37.94	5.58	26.35
	C-MD	4.4	38.62	5.98	19.3
3 hr	CE	5	43.45	21.47	51.83
	C-CD	5.03	42.99	7.48	31.33
	C-MD	4.8	42.07	8	19.75
CE					

CE= curcumin extract, C-CD =encapsulated curcumin extract with  $\beta$  -cyclodextrin, C-MD =encapsulated curcumin extract with maltodextrin.

The vulnerability of the diketone in curcumin molecule is the reason of its sensitivity as explained by (Suresh *et al.*, 2009). The forms of curcumin in acidic and basic conditions are presented in fig.9 and the degradation products of curcumin is explained by (Lin *et al.*, 2000) in fig(10.) and Fig (11) revealed compound formed in basic condition.



Keto form

Enol form

Figure 9. Curcumin in Acidic and Basic condition (Kumavat *et al.*, 2013).



Figure 10. Degradation products of curcumin at basic condition(Kumavat *et al.*, 2013).



Figure 11. Red coloured compound formed above pH 7 (Kumavat *et al.*, 2013).

#### Differential Scanning Calorimetry (DSC):

DSC is a method to detect and confirm the formation of the inclusion complex. When host/guest interaction happened, the physical properties of the guest molecule change, resulting in shifting of its characteristic peaks or disappearance In addition, a change in thermal stability.(da Silva *et al.*, 2021), and (Singh *et al.*, 2018).

The DSC curve of pure  $\beta$ -CD as shown in Figure (12), exhibited an endothermic peak at about 107.33 °C corresponding to the dehydration in the cavity of  $\beta$ -CD. This result was closer to the result by Singh *et al.* (2018); Zhang *et al.* (2018b).

The thermograms of GE presented in Figure (13) exhibited two characteristic endothermic peaks at 28.88 °C and 32.61 °C in accordance with the DSC results of 6-gingerol presented by (Pais *et al.*, 2020). While the DSC profile of G-CD presented in Figure (14) exhibited a new absorption peak at higher temperature 132.95 °C and 346.06 °C than that of  $\beta$ -CD with the absence of 6-G characteristic peak. This shifting and disappearance of peaks is clear evidence of the formation of G-CD inclusion complex and improvement of complex stability.

The DSC of MD in Figure (15) showed an endothermic peak at  $85.09^{\circ}$ C and other peaks at  $264^{\circ}$ C and  $307^{\circ}$ C while G-MD presented in Figure (16), which exhibited three peaks at  $163.35^{\circ}$ C,  $214.26^{\circ}$ C and  $319.43^{\circ}$ C. The absence of characteristic peak in G-MD beside the illustrated shifting indicates the formation of G-MD inclusion complex and improvement of its thermal stability.



Figure 12. DSC thermograms of betacyclodextrin (β-CD).



Figure 13. DSC thermograms of ginger extract(G-E).



Figure 14. DSC thermograms of encapsulated ginger extract with betacyclodextrin(G-CD).



Figure 15. DSC thermograms of maltodextrin (MD).



Figure 16. DSC thermograms of encapsulated ginger extract with maltodextrin(G-MD).

DSC thermogram for curcumin extract (C-E) was presented in Figure (17). C-E showed three peaks at 71.25 C, 91.80 C and 97.12C respectively, while Figure (18) showed two peaks at 92.03 and 328 for C-CD and absence of curcumin characteristic peaks and CD endothermic peaks indicating the formation of C-CD inclusion complex. Figure (19) presents DSC thermogram of C-MD which exhibited clear shifting for curcumin characteristic peaks and MD endothermic peaks indicating formation of C-MD inclusion complex and improvement of its thermal stability. This increase in thermal stability of encapsulated curcumin is in accordance with those mention by (E. I. Paramera *et al.*, 2011b).



Figure 17. DSC thermograms of curcumin extract(C-E).



Figure 18. DSC thermograms of encapsulated curcumin extract with betacyclodextrin(C-CD).



Figure 19. DSC thermograms of encapsulated curcumin extract with maltodextrin(C-MD).

#### In vitro- gastro digestion procedure

Reported data in table (9) revealed TPC of the prepared plant extracts and encapsulated plant extracts before and after invitro gastro-intestinal digestion. The results show a decrease in the total phenols of the G-CD after digestion was 32.8mg GAE /100 g DM, while it was 49.8mg GAE /100 g DM before digestion. The decrease in TPC in all samples after digestion is due to exposure to degradation of phenols by the effect of pH and digestive enzymes as described by (Ortega *et al.*, 2011) thus its availability and solubility are affected. this is in accordance with several studies (Lucas-Gonzalez *et al.*, 2016; Lucas-González *et al.*, 2018; Rodríguez-Roque *et al.*, 2015). They concluded that polymerization, interaction with other nutrients, or oxidation reactions may lead to phenol-derivatives formation and decrease in TPC.

Table 9. Total phenols(mg GAE /100 g DM) of encapsulated Ginger extract and Curcumin extract before and after in-vitro gastrointestinal digestion.

	angeotion	
Plant	Before in-vitro	After in-vitro
Sample	gastrointestinal digestion	gastrointestinal digestion
GE	43.61±4.8	28.89±3.1
G-CD	49.81±3.9	32.8±2.9
G-MD	36.58±2.8	22.63±1.8
CE	6175±32.2	3965±38.1
C-CD	525.66 12.8	306.89±22.4
C-MD	662.5±14.2	407.6±22.8
CT I		1 1 1 1 1 0

GE= ginger extract, G-CD =encapsulated ginger extract with βcyclodestrin, G-MD =encapsulated ginger extract with maltodextrin,CE= curcumin extract, C-CD =encapsulated curcumin extract with β-cyclodestrin, C-MD =encapsulated curcumin extract with maltodextrin.Each value is expressed as mean  $\pm$  S.D (n = 5).

The degradation products of gingerol after digestion is illustrated in fig.(20). It is worth mentioning that about 50% of TPC are still stable prelude to absorption in intestinal.



Figure 20. Proposed mechanism of degradation of gingerol and shogaol in simulated gastric and intestinal fluid.

The radical scavenging activity (%ARE) before and after invitro gastro-intestinal digestion of the encapsulated plant samples were investigated and recorded in table 10. The %ARE performed a tendency of percentage decrease because of TPC decrease. The correlation between TPC and the radical scavenging activity is because. The ability of hydroxyl groups in phenols to scavenge free radicals which is the responsible of its antioxidant activity (Tosun *et al.*, 2009).

# Table 10. Radical scavenging activity % of encapsulated Ginger extract and Curcumin extract before and

	aner in-vitro gastrointestinai digestion.						
Plant	Before in-vitro	After in-vitro					
Sample	gastrointestinal digestion	gastrointestinal digestion					
GE	38.01±2.8	6.03±0.15					
G-CD	439±7.1	6.9±0.01					
G-MD	50.22±5.4	6.02±0.02					
CE	43.59±2.8	9.9±0.33					
C-CD	52.04±3.1	15.3±0.26					
C-MD	47.6 <u>+</u> 2.1	12.2±0.23					

#### CONCLUSION

In conclusion, the encapsulation of plant extracts leads to an improvement in bioavailability through enhancement the properties and stability of bioactive components (phenols, flavonoids and vitamins), while reducing the degradation of bioactive components when exposed to thermal stress and pH, which enables use encapsulated plant extracts in a wide range of temperatures and pH in the food industry.

#### REFERENCES

- Al Jumayi, H. A., Allam, A. Y., El-Beltagy, A. E., Algarni, E. H., Mahmoud, S. F., El Halim Kandil, A. A. (2022). Bioactive Compound, Antioxidant, and Radical Scavenging Activity of Some Plant Aqueous Extracts for Enhancing Shelf Life of Cold-Stored Rabbit Meat. *Antioxidants (Basel)*, 11(6). doi :10. 3390 /antiox 11061056
- Andriyani, R., Budiati, T., Pudjiraharti, S. (2015). Effect of Extraction Method on Total Flavonoid, Total Phenolic Content, Antioxidant and Anti-bacterial Activity of Zingiberis Officinale Rhizome. *Procedia Chemistry*, 16, 149-154. doi: 10. 1016 /j. proche.2015.12.023
- AOAC. (2020). INTERNATIONAL Annual Meeting & Exposition, Building the Future of Analytical Science, was held September 8-24,.
- Archontaki, H. A., Vertzoni, M. V., Athanassiou-Malaki, M. H. (2002). Study on the inclusion complexes of bromazepam with beta- and beta-hydroxypropylcyclodextrins. *J Pharm Biomed Anal*, 28(3-4), 761-769. doi:10.1016/s0731-7085(01)00679-3
- Bhandari, S. R., Kwak, J.-H. (2015). Chemical Composition and Antioxidant Activity in Different Tissues of Brassica Vegetables. *Molecules*, 20(1). doi:10.3390 /molecules20011228
- Bhattarai, S., Tran, V. H., Duke, C. C. (2001). The stability of gingerol and shogaol in aqueous solutions. *J Pharm Sci*, 90(10), 1658-1664. doi:10.1002/jps.1116

- Bin, L. (2022). Microencapsulation of roselle anthocyanins with β-cyclodextrin and proteins enhances the thermal stability of anthocyanins. *Journal of food processing and preservation*, v. 46(no. 5), pp. e16612--12022 v.16646 no.16615. doi:10.1111/jfpp.16612
- Cano-Chauca, M., Stringheta, P. C., Ramos, A. M., Cal-Vidal, J. (2005). Effect of the carriers on the microstructure of mango powder obtained by spray drying and its functional characterization. *Innovative Food Science & Emerging Technologies*, 6(4), 420-428. doi:https://doi.org/10.1016/j.ifset.2005.05.003
- Caparino, O. A., Tang, J., Nindo, C. I., Sablani, S. S., Powers, J. R., Fellman, J. K. (2012). Effect of drying methods on the physical properties and microstructures of mango (Philippine 'Carabao' var.) powder. *Journal of Food Engineering*, 111(1), 135-148. doi :https: //doi. org /10.1016/j.jfoodeng.2012.01.010
- Cassani, R., Estarellas, M., San-Martin, R., Fraga, F. J., Falk, T. H. (2018). Systematic review on resting-state EEG for Alzheimer's disease diagnosis and progression assessment. *Disease markers*, 2018.
- Celep, E., Aydın, A., Kırmızıbekmez, H., Yesilada, E. (2013). Appraisal of in vitro and in vivo antioxidant activity potential of cornelian cherry leaves. *Food and chemical toxicology*, 62, 448-455.
- da Silva, J. A., Sampaio, P. A., Dulcey, L. J. L., Cominetti, M. R., Rabello, M. M., Rolim, L. A. (2021). Preparation and characterization of [6]-gingerol/β-cyclodextrin inclusion complexes. *Journal of Drug Delivery Science and Technology*, 61, 102103. doi:https://doi.org/10.1016/j.jddst.2020.102103
- Fernandes, F. H. A., Santana, C. P., Santos, R. L., Correia, L. P., Conceição, M. M., Macêdo, R. O., Medeiros, A. C. D. (2013). Thermal characterization of dried extract of medicinal plant by DSC and analytical techniques. *Journal of Thermal Analysis and Calorimetry*, 113(2), 443-447. doi:10.1007/s10973-012-2807-3
- Grgić, J., Šelo, G., Planinić, M., Tišma, M., Bucić-Kojić, A. (2020). Role of the Encapsulation in Bioavailability of Phenolic Compounds. *Antioxidants (Basel)*, 9(10). doi:10.3390/antiox9100923
- Hazra, K., Kumar, R., Sarkar, B., Chowdary, D. Y., Devgun, M., Ramaiah, M., Educational, I. (2015). UV-VISIBLE SPECTROPHOTOMETRIC ESTIMATION OF CURCUMIN IN NANOFORMULATION. *International Journal of Pharmacognosy*, 2, 127-130. doi: 10.13040/ JJPSR. 0975-8232.JJP.2(3).127-30
- Hewlings, S. J., Kalman, D. S. (2017). Curcumin: A Review of Its Effects on Human Health. *Foods*, 6(10). doi:10.3390/foods6100092
- Jayaprakasha, G., Singh, R., Sakariah, K. K. (2001). Antioxidant activity of grape seed (Vitis vinifera) extracts on peroxidation models in vitro. *Food Chemistry*, 73, 285-290. doi:10.1016/S0308-8146(00)00298-3
- Khalifa, I., Mengli, L., Mamet, T., Li, C. (2019). Maltodextrin or gum Arabic with whey proteins as wall-material blends increased the stability and physiochemical characteristics of mulberry microparticles. *Food Bioscience*, 31, 100445. doi :10 .1016 /j. fbio.2019.100445

- Khiralla, Ali, H. M. (2020). Bioavailability and antioxidant potentials of fresh and pasteurized kiwi juice before and after in vitro gastrointestinal digestion. *Journal of Food Science and Technology*, 57(11), 4277-4285.
- Khiralla, G. M. (2015). Antibiofilm and anti-adhesive effects of ginger against some food-related pathogens. J Food Res Technol, 3(3), 87-96.
- Kuck, L. S., Noreña, C. P. (2016). Microencapsulation of grape (Vitis labrusca var. Bordo) skin phenolic extract using gum Arabic, polydextrose, and partially hydrolyzed guar gum as encapsulating agents. *Food Chem*, 194, 569-576. doi :10. 1016 /j. foodchem. 2015.08.066
- Kumavat, S. D., Borole, P., Mishra, P. A., Shenghani, K., Duvvuri, P. (2013). DEGRADATION STUDIES OF CURCUMIN.
- Labuschagne, P. (2018). Impact of wall material physicochemical characteristics on the stability of encapsulated phytochemicals: A review. *Food Research International*, 107, 227-247. doi: https://doi .org/10.1016/j.foodres.2018.02.026
- Lin, J. K., Pan, M. H., Lin-Shiau, S. Y. (2000). Recent studies on the biofunctions and biotransformations of curcumin. *Biofactors*, 13(1-4), 153-158. doi:10.1002/biof.5520130125
- Lindsey, M. E., Xu, G., Lu, J., Tarr, M. A. (2003). Enhanced Fenton degradation of hydrophobic organics by simultaneous iron and pollutant complexation with cyclodextrins. *The Science of the total environment*, 307(1-3), 215-229. doi: 10. 1016/ s0048 -9697 (02)00544-2
- López-Tobar, E., Blanch, G. P., Ruiz del Castillo, M. L., Sanchez-Cortes, S. (2012). Encapsulation and isomerization of curcumin with cyclodextrins characterized by electronic and vibrational spectroscopy. *Vibrational Spectroscopy*, *62*, 292-298. doi:https://doi.org/10.1016/j.vibspec.2012.06.008
- Loron, A., Gardrat, C., Tabary, N., Martel, B., Coma, V. (2021). Tetrahydrocurcumin encapsulation in cyclodextrins for water solubility improvement: Synthesis, characterization and antifungal activity as a new biofungicide. *Carbohydrate Polymer Technologies and Applications*, 2, 100113. doi: https ://doi.org/10.1016/j.carpta.2021.100113
- Lucas-Gonzalez, R., Navarro-Coves, S., Pérez-Álvarez, J. A., Fernández-López, J., Muñoz, L. A., Viuda-Martos, M. (2016). Assessment of polyphenolic profile stability and changes in the antioxidant potential of maqui berry (Aristotelia chilensis (Molina) Stuntz) during in vitro gastrointestinal digestion. *Industrial crops and products*, 94, 774-782.
- Lucas-González, R., Viuda-Martos, M., Pérez Álvarez, J. A., Fernández-López, J. (2018). Changes in bioaccessibility, polyphenol profile and antioxidant potential of flours obtained from persimmon fruit (Diospyros kaki) co-products during in vitro gastrointestinal digestion. *Food Chem*, 256, 252-258. doi:10.1016/j.foodchem.2018.02.128
- Marcolino, V. A., Zanin, G. M., Durrant, L. R., Benassi, M. D. T., Matioli, G. (2011). Interaction of curcumin and bixin with β-cyclodextrin: complexation methods, stability, and applications in food. *Journal of agricultural and food chemistry*, 59(7), 3348-3357.

- Meena, K., Meena, R., Kumawat, S. (2013). Effect of sulphur and iron fertilization on yield attributes, yield and nutrient uptake of mungbean (Vigna radiata). *Indian Journal of Agricultural Science*, 83(4), 472-476.
- Naik, G. H., Priyadarsini, K. I., Satav, J. G., Banavalikar, M. M., Sohoni, D. P., Biyani, M. K., Mohan, H. (2003). Comparative antioxidant activity of individual herbal components used in Ayurvedic medicine. *Phytochemistry*, 63(1), 97-104. doi:10.1016/s0031-9422(02)00754-9
- Narayanan, M., Shanmugam, S., Suresh, P. M. (2018). Physical properties of microencapsulated anthocyanin obtained by spray drying of Red Amaranthus extract with maltodextrin. *Malaysian Journal of Nutrition*, 24(1).
- Olds, T., Tomkinson, G., Ferrar, K., Maher, C. (2011). Reply to Ortega *et al. International journal of obesity* (2005), 35. doi:10.1038/ijo.2011.128
- Ortega, N., Macià, A., Romero, M.-P., Reguant, J., Motilva, M.-J. (2011). Matrix composition effect on the digestibility of carob flour phenols by an in-vitro digestion model. *Food Chemistry*, 124(1), 65-71. doi:https://doi.org/10.1016/j.foodchem.2010.05.105
- Pais, J. M., Pereira, B., Paz, F. A. A., Cardoso, S. M., Braga, S. S. (2020). Solid γ-cyclodextrin inclusion compound with gingerols, a multi-component guest: Preparation, properties and application in yogurt. *Biomolecules*, 10(2), 344.
- Paramera, E., Konteles, S., Karathanos, V. (2011a). Microencapsulation of curcumin in cells of Saccharomyces cerevisiae. *Food Chemistry*, 125, 892-902. doi:10.1016/j.foodchem.2010.09.063
- Paramera, E. I., Konteles, S. J., Karathanos, V. T. (2011b). Stability and release properties of curcumin encapsulated in Saccharomyces cerevisiae, βcyclodextrin and modified starch. *Food Chemistry*, *125*(3), 913-922. doi :https://doi.org/ 10 .1016 /j.foodchem.2010.09.071
- Paramera, E. I., Konteles, S. J., Karathanos, V. T. (2011c). Stability and release properties of curcumin encapsulated in Saccharomyces cerevisiae, βcyclodextrin and modified starch. *Food Chemistry*, 125, 913-922.
- Popuri, A., K , pagala, B. (2013). Extraction of Curcumin From Turmeric Roots International Journal of innovative Research & studies, 2(4), 290-299.
- Prieto, P., Pineda, М., Aguilar, M. (1999). Spectrophotometric quantitation of antioxidant formation capacity through the of а phosphomolybdenum complex: specific application to the determination of vitamin E. Anal Biochem, 269(2), 337-341. doi:10.1006/abio.1999.4019
- Radošević, K., Srček, V., Cvjetko Bubalo, M., Rimac, S., Takács, K., Radojcic Redovnikovic, I. (2017). Assessment of glucosinolates, antioxidative and antiproliferative activity of broccoli and collard extracts. *Journal of Food Composition and Analysis*, 61. doi:10.1016/j.jfca.2017.02.001
- Rodríguez-Roque, M. J., Ancos, B. d., Sánchez-Moreno, C., Cano, M. P., Elez-Martínez, P., Martín-Belloso, O. (2015). Impact of food matrix and processing on the in vitro bioaccessibility of vitamin C, phenolic compounds, and hydrophilic antioxidant activity from fruit juice-based beverages. *Journal of Functional Foods, 14*, 33-43.

- Sahne, F., Mohammadi, M., Najafpour, G., Moghadamnia, A. (2016). Extraction of bioactive compound curcumin from turmeric (Curcuma longa L.) via different routes: A comparative study. *13*, 173-180.
- Saokham, P., Muankaew, C., Jansook, P., Loftsson, T. (2018). Solubility of Cyclodextrins and Drug/Cyclodextrin Complexes. *Molecules*, 23(5). doi:10.3390/molecules23051161
- Shahrajabian, M. H., Sun, W., Cheng, Q. (2019). Clinical aspects and health benefits of ginger (Zingiber officinale) in both traditional Chinese medicine and modern industry. Acta Agriculturae Scandinavica, Section B — Soil & Plant Science, 69(6), 546-556. doi:10.1080/09064710.2019.1606930
- ShindeSachin, K., Nirmala, G., BanerjeeSubir, K., JadhavSuresh, L. (2012). DEVELOPMENT AND VALIDATION OF UV SPECTROSCOPIC METHOD FOR THE QUICK ESTIMATION OF GINGEROL FROM ZING IBER OFFICINALE RHIZOME EXTRACT.
- Singh, R. P., Gangadharappa, H. V., Mruthunjaya, K. (2018). Phytosome complexed with chitosan for gingerol delivery in the treatment of respiratory infection: In vitro and in vivo evaluation. *Eur J Pharm Sci*, 122, 214-229. doi:10.1016/j.ejps.2018.06.028
- Suresh, D., Gurudutt, K. N., Srinivasan, K. (2009). Degradation of bioactive spice compound: curcumin during domestic cooking. *European Food Research* and Technology, 228(5), 807-812. doi :10 .1007 /s00217-008-0993-9
- Tonon, R., Brabet, C., Hubinger, M. (2008). Influence of process conditions on the physicochemical properties of a??ai (Euterpe oleraceae Mart.) powder produced by spray drying. *Journal of Food Engineering*, 88, 411-418. doi:10.1016/j.jfoodeng.2008.02.029

- Tosun, M., Ercisli, S., Sengul, M., Ozer, H., Polat, T., Ozturk, E. (2009). Antioxidant properties and total phenolic content of eight Salvia species from Turkey. *Biol Res*, 42(2), 175-181.
- Tumbas Šaponjac, V., Čanadanović-Brunet, J., Ćetković, G., Jakišić, M., Vulić, J. J., Stajčić, S., Šeregelj, V. (2020). Optimisation of Beetroot Juice Encapsulation by Freeze-Drying. *Polish Journal of Food and Nutrition Sciences*, 70(1), 25-34. doi:10.31883/pjfns/115153
- Tupuna, D. S., Paese, K., Guterres, S. S., Jablonski, A., Flôres, S. H., Rios, A. d. O. (2018). Encapsulation efficiency and thermal stability of norbixin microencapsulated by spray-drying using different combinations of wall materials. *Industrial Crops and Products*, 111, 846-855. doi :https :// doi. org /10 .1016 /j.indcrop.2017.12.001
- Wang, Y., Lv, F., Bie, X. (2009). Study on microencapsulation of curcumin pigments by spray drying. *European Food Research and Technology*, 229, 391-396. doi:10.1007/s00217-009-1064-6
- Yamashita, C., Chung, M. M. S., dos Santos, C., Mayer, C. R. M., Moraes, I. C. F., Branco, I. G. (2017). Microencapsulation of an anthocyanin-rich blackberry (Rubus spp.) by-product extract by freezedrying. *LWT*, *84*, 256-262. doi :https :// doi .org /10.1016/j.lwt.2017.05.063
- Zhang, Y., Zhang, H., Wang, F., Wang, L.-X. (2018a). Preparation and properties of ginger essential oil βcyclodextrin/chitosan inclusion complexes. *Coatings*, 8(9), 305.
- Zhang, Y., Zhang, H., Wang, F., Wang, L.-X. (2018b). Preparation and Properties of Ginger Essential Oil β-Cyclodextrin/Chitosan Inclusion Complexes. *Coatings*, 8, 305. doi:10.3390/coatings8090305

## الاتاحة الحيوية، الثبات وقدرات مضادات الأكسدة للزنجبيل والكركمين قبل وبعد عملية الكبسلة

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معهد الدر اسات العليا والبحوث الزر اعية في المناطق القاحلة – جامعة عين شمس

## الملخص

يعد الزنجبيل (Zingiber officinale) والكركم (Curcuma longa L) من المصادر الطبيعية الغنية بالمواد الفعالة ذات التأثير الطبي والعلاجي ، ولكن الاستفادة من هذه المواد محدودة بسبب حساسيتها للكثير من العوامل مثل الحرارة ودرجات الحموضة المختلفة و عوامل الهضم عوامل أخرى ، وكذلك انخفاض قابليتها للنوبان في الماء لذلك كانت عملية الحماية لهذه المركبات وكذلك رفع قابليتها للنوبان عن طريق عملية الكبسلة بواسطة التجفيد و باستخدام المركبين : بيتاسيكلودكسترين و مالتودكسترين هو الهدف من هذه الدراسة. أشارت النتائج إلى ارتفاع نوبان C-MD إلى 83.68 ، MD-P إلى 95.97 % مقارنة بمستخلص الكوركيومين نفسه 19.61 % ومستخلص الزنجبيل 28.14 %. كذلك زاد المحتوى من الفينو لات في (G-CD) إلى 83.61 ، MD-A إلى 95.97 % مقارنة بمستخلص الكوركيومين نفسه 19.61 % ومستخلص الزنجبيل 28.14 %. كذلك زاد المحتوى من الفينو لات في (G-CD) إلى 18.18 ، ما مع موزن جلف بينما في مستخلص الكوركيومين نفسه 19.61 % ومستخلص الزنجبيل 28.14 % الفينو لات في (G-CD) إلى 12.11 % ما مع موزن جلف بينما في مستخلص الكوركيومين نفسه 19.61 % ومستخلص الزنجبيل 28.14 إلى 10.22 % الما مع ما 100 جم وزن جلف بينما في مستخلص الزنجبيل فكن 3.61 ملحم / 100 مع. الإتاحة الحيوية للقوة الاختز الية للمستخلصات المكبسلة وصلت إلى 10.22 % 111.0 % ، 12.15 % لكل من G-CD 6 -MD ، G-MD ، G-CD على الترتيب. كذلك تم اختبار ثبات هذه المعتدات الحرارة و درجة ال HP المختلفة فلو حظ زيادة شبات كل من CD ، 8.011 % ، 20.5 % الكل من CD-G، معقدات الكوركيومين عند الدرجات المتعادلة والقاحدية مقارنة بالمستخلصات غير المكبسلة إلى ولي ديادة شبات كل من G-D ، ولكل من 20.60 حمار 20.60 حمان الكرديومين عند الدرجات المتعادلة والقاحدية مواني والم مقرب الكلية في -G وتما درجات الحموضية المختلفة إلى الإيرات الفوبان ، الثبات الحراري المعاد الحراري ، المعندات والم حمال والذريول والم عدراري ، الثبات الحراري ، وتحمل درجات الحموضية المختلفة بالمنتذلي الذوبان الذوبان الدر الده الي أن كبسلة مستخلصي الزنجبيل والكركم أدى إلى تحسن الذوبان ، الثبات الحراري ، وتحمل درجات الحموضية المختلفة بالإضافة إلى الأوبانة الحوبة .