Pomegranate peels phenolics encapsulated in edible fruit fiber: storage stability and ingredient for functional foods

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Pomegranate

Pomegranate is an ancient fruit originating from the Middle East and nowadays the global pomegranate production is around 2 million tons

The most important growing regions are:

- China
- Iran
- Egypt
- Turkey
- Spain
- U.S.A.

24% Peel

14% Seeds

62% Juice

Composition-Polyphenol Content of Pomegranate Peel

Component	Content (%)
Total solids	96.00
Moisture	4.00
Total sugars	31.38
Proteins	8.72
Crude Fiber	21.06
Fat	9.40
Ash	5.00
Total phenolics	8.10

Aguilar et al.,2008; Ullah et al.,2012

- Antioxidant activity
- Anti-mutagenic activity
- Anti-hypertension activity
- Anti-inflammatory activity
- Anti-atherosclerotic activity

Phenolic compound	Content (mg/100 g dry matter)
Ellagic acid	44.19
Catechin	868.40
Gallic acid	125.80
Protocatechol	4.17
Vanilline	3.91
Caffeic acid	60.46
Ferulic acid	5.89
p-coumaric acid	17.64
Others	8.20

Rowayshed et al., 2013

Exploitation of Pomegranate Peels

Pomegranate 100 kg

Peels 24 kg

Seeds 14 kg

Fodder

Food Industry

- Ice cream
- Tea

Cosmetics

Proposed Process for Pomegranate Peels Application in Food Industry

Pomegranate Peels

Drying

Grinding

Solvent

Ultrasound-assisted extraction

Fodder

Filtration

Recycled solvent

Evaporation

Wall material

Drying

Phenolics

Emulsification

Encapsulation by spray drying

Food additives

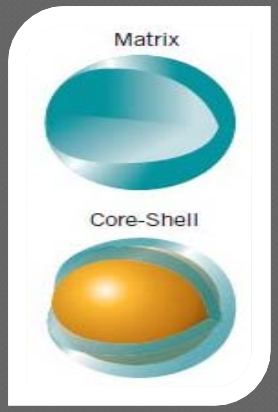
Microcapsules of phenolics

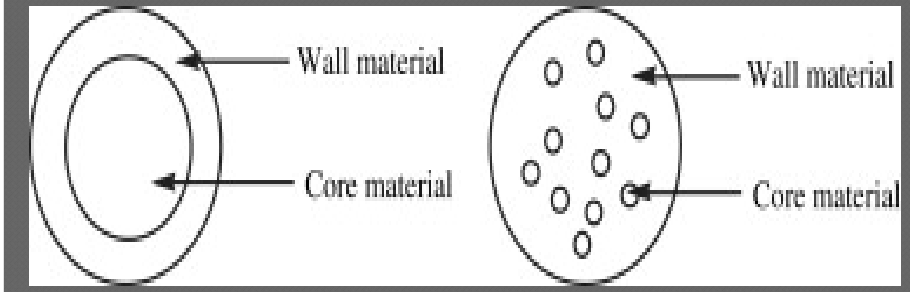
Kaderides et al., 2015

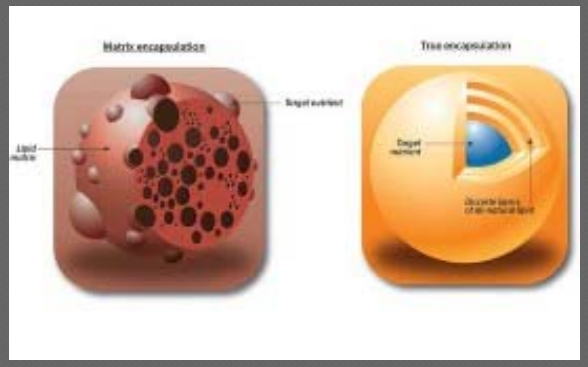
Why Encapsulation of Phenolic Compounds

- Increase of their stability during storage and passage through the gastrointestinal tract
- Improvement of color
- Masking of astringency
- Suitability for use as an additive in functional foods

Fang & Bhandari, 2010

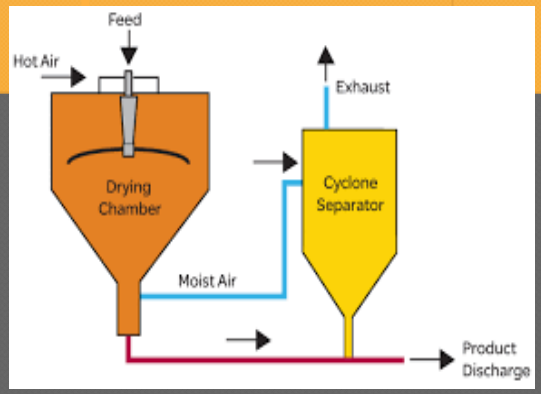






Encapsulation methods

Method of encapsulation	Encapsulation efficiency	Reference
Extrusion	89.39%	Belščak-Cvitanovic et al., 2011
Rapid Extraction of Supercritical Solution	79.78%	Santos et al., 2013
Formation of multiple emulsion using a rotating disk reactor	80.00%	Akhtar et al., 2014
Freeze drying	75.50%; 97.22%	da Rosa et al., 2014; Saikia et al., 2015
Spray drying	99.80%	Kaderides et al., 2015



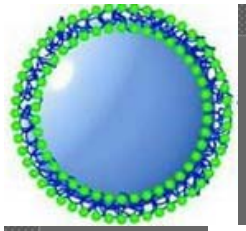
Wall material characteristics

1. Good rheological properties at high concentration
2. Disperse or emulsify the active material and stabilize the emulsion produced
3. Chemical non reactivity with the active core materials
4. Seal and hold the active material within its structure during processing/storage
5. Provide maximum protection to the active material against environmental conditions
6. Acceptable solubility of the solvent to the food industry

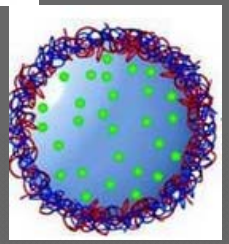
Desai & Park, 2005

Wall Materials Used for Encapsulation of Phenolic Compounds

Phenolic extract	Wall material	References
Spray drying		
Pomegranate peel extract	Maltodextrin; Whey protein concentrate; Skim milk powder	Kaderides et al., 2015
Carrot extract	Maltodextrin	Ersus &Yurdagel, 2008
Olive leaf extract	Chitosan	Kosaraju et al., 2006
Soybean extract	Maltodextrin; Starch	Georgetti et al., 2008
Bilberry extract	Whey protein concentrate	Betz et al., 2012
Apple extract; Olive leaf extract	Sodium caseinate; Lecithin	Kosaraju et al., 2008
Co-crystallization		
Yerba Mate extract	Calcium alginate	Deladino et al., 2008
Green tea EGCG extract	Gelatin	Shutava et al., 2009
Blackcurrant extract	Glucan	Xiong et al., 2006
Freeze drying		
Cloudberry extract	Maltodextrin DE 5-8 & DE18,5	Laine et al., 2008
Hibiscus tea extract	Pullulan	Gradinaru et al., 2003



Wall Materials Suitable for Encapsulation of Phenolic Compounds



Wall material with appropriate encapsulation properties

- Carbohydrates
- Proteins
  - → Undesired taste
  - → Unnatural additives
  - → Replacement with alternative products
- Insoluble dietary fibres
  - → Complex carbohydrates
  - → Strong absorption properties

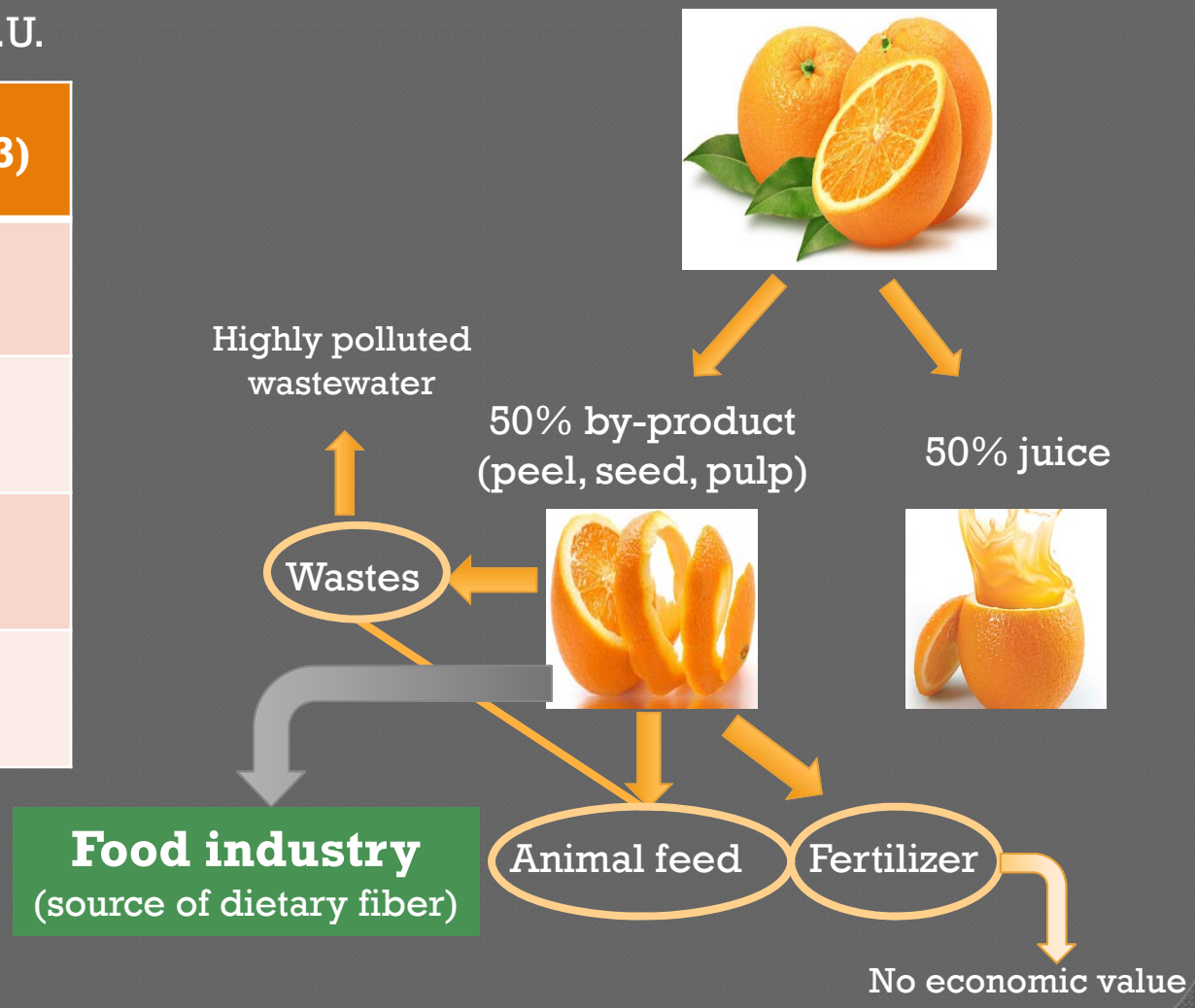
Natural dietary fibres

- Soluble dietary fibres — Assist regular bowel movements and flushing the intestinal system of undesirable materials
- Insoluble dietary fibres — Slow down the metabolism rates of sugars and form a lining gel within the intestines

Production and Exploitation of Orange Fruit

Production of oranges in E.U.

Country	Tons (2013)
Spain	2 933 800
Italy	1 950 000
Greece	914 000
Portugal	206 300



Incorporation of Pomegranate Peel Extract in Foods

Product	Activity	Reference
Encapsulated pomegranate peel extract		
Hazelnut paste	Antioxidant	Kaderides et al., 2015
Ice cream	Antioxidant	Cam et al., 2014
Pomegranate peel extract		
Shrimps Meat pate	Antimicrobial	Basiri et al., 2015; Hayrapetyan et al., 2012
Bread	Antioxidant	Paari et al., 2012; Altunkaya et al., 2013
Sunflower oil Cooked chicken patties	Antioxidant and Antimicrobial	Iqbal et al., 2008; Kanatt et al., 2010; Naveena et al., 2008

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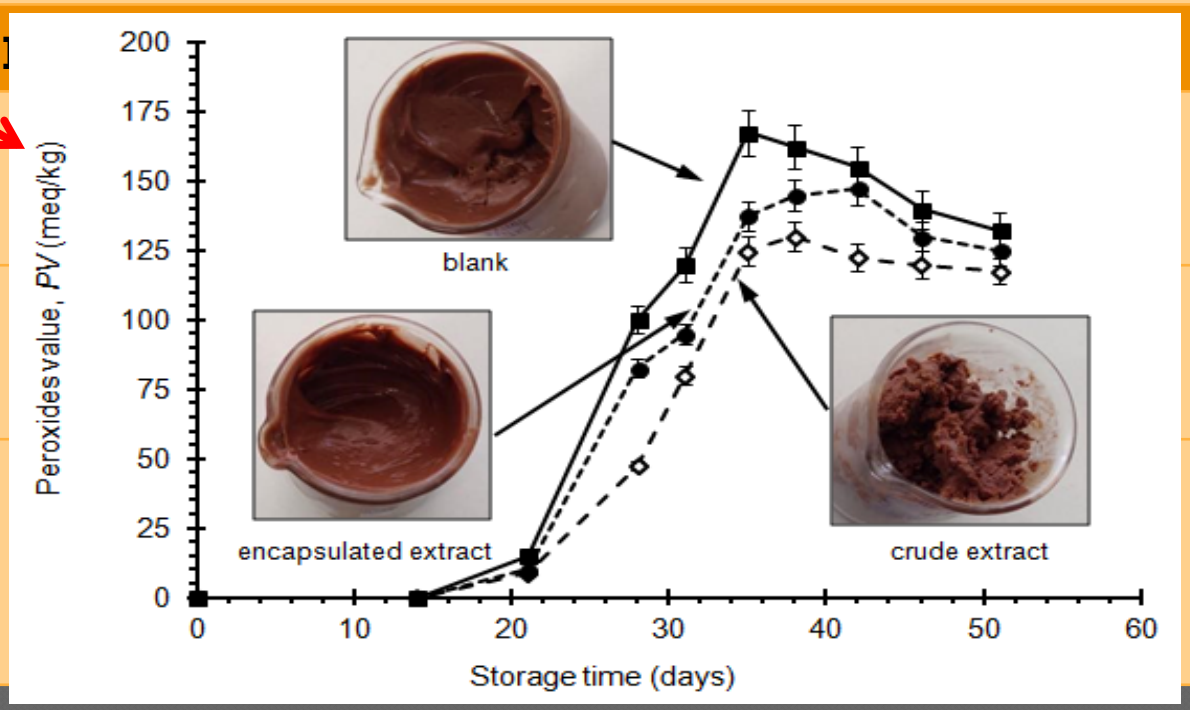


Objective

The exploitation of pomegranate and orange wastes *based on:*

- *Ultrasound-assisted extraction of phenolic compounds from pomegranate peel*
- *Encapsulation of extract by spray drying using orange juice industry by-product as wall material*

Study of:

1. *Storage stability of crude and encapsulated pomegranate peel extract*
2. *Incorporation of crude and encapsulated extract in foods:*
    a. *Peanut butter*
    b. *Milk powder*
    c. *Fresh juice*

Integrated Process for Orange Wastes Application as Wall Material for Encapsulation

Orange

Juice production → Juice

Orange wastes

Hot water – 100 °C → **Boiling** 20 min

Washing

Drying 60 °C, 48 h

Grinding

Sieving

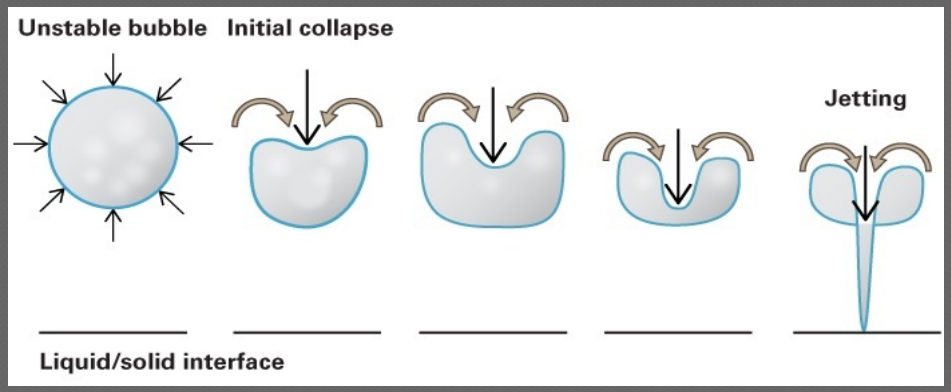
Orange wastes powder

Pomegranate Peel Extract – Optimized Conditions of Ultrasound Assisted Extraction

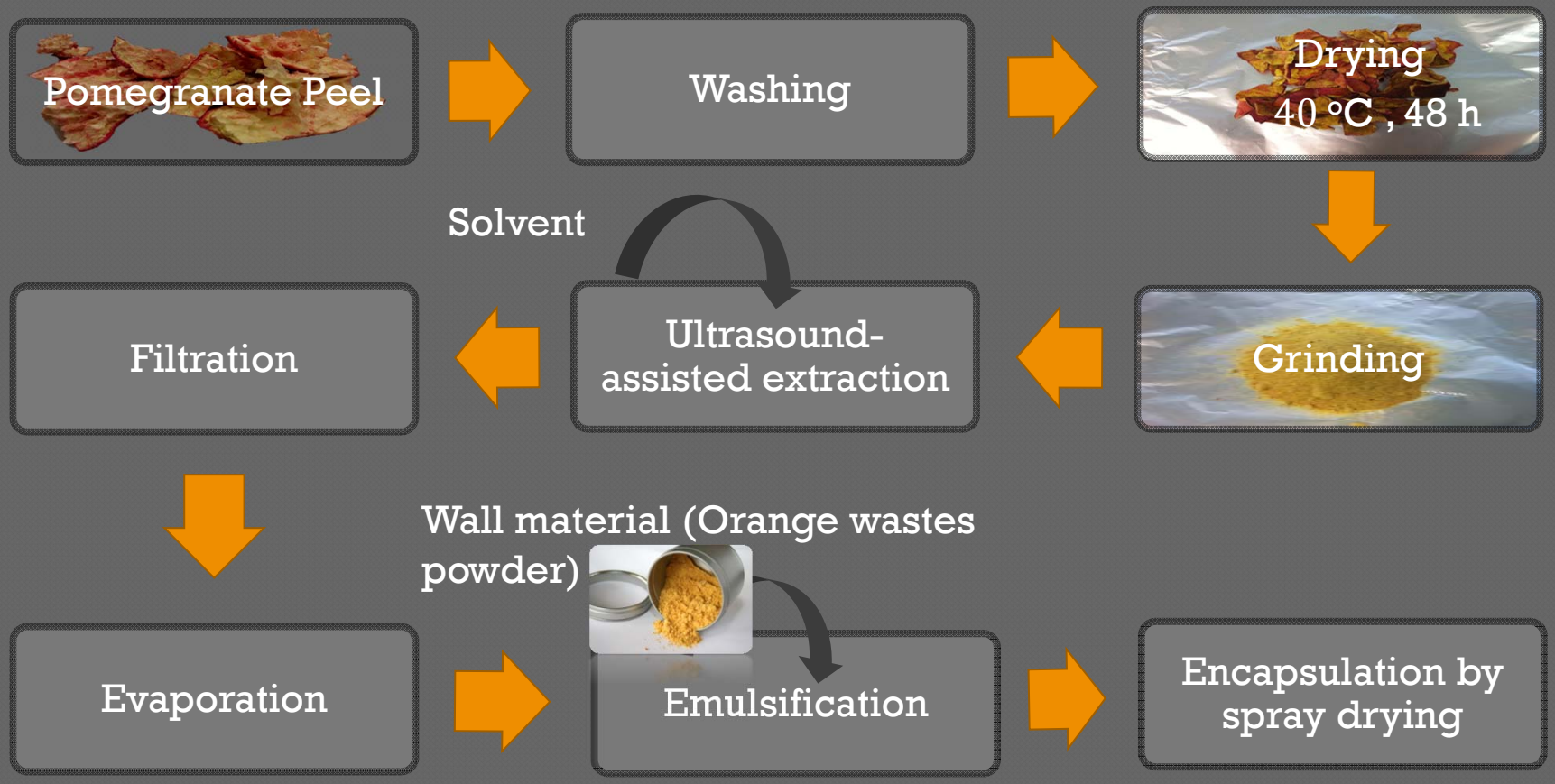
1. **Extraction temperature:** *35 °C*
2. **Solvent type:** *Water*
3. **Solvent/Solid ratio:** *32/1*
4. **Amplitude level:** *40% (50 W)*
5. **Pulse duration/Pulse interval ratio***: 7/6*
6. **Extraction time:** *10 min*

130 W, 20 kHz VCX-130 Sonics and Materials (Danbury, CT, USA) with Ti–Al–V probe (13 mm)

Kaderides et al., 2015



Integrated Process for Encapsulation of Pomegranate Peel Extract in Orange Wastes Powder



Encapsulation of Pomegranate Peels Extract – Optimized Conditions of Spray Drying

1. **Wall material:** Orange wastes
2. **Inlet air temperature:** 162 °C
3. **Feed solids concentration:** 5 %
4. **Ratio of core to wall material:** 1/9
5. **Drying air flow rate:** 50%
6. **Flow rate of compressed air for atomization:** 0.80 m^3/h

- Concurrent
- Two – fluid nozzle atomization
- Peristaltic pump for feed

Buchi, B-191,
Buchi Laboratoriums-Technik,
Flawil, Switzerland

Storage Stability

- Crude pomegranate peel extract
- Encapsulated pomegranate peel extract

Shelf-life test at 60°C for 40 days

Measurement of:

- ✓ Antioxidant activity
- ✓ Total phenolics content
- ✓ Color

Incorporation of Phenolic Capsules in Foods

- **PRODUCT:**

  a. Peanut butter

  b. Milk powder (full-fat)

  Shelf-life test at 60°C for 30 days

  c. Fresh juice (apple, orange, carrot) → Shelf-life test at 4°C for 30 days

- **ADDITIVE:** Phenolic extract (Crude and encapsulated)
- **PHENOLICS CONCENTRATION:** 5000 ppm

3 samples were tested:

- Sample with encapsulated extract
- Sample with crude extract
- Control sample

Measurement of:

- ✓ Antioxidant activity
- ✓ Total phenolics content
- ✓ Oxidation stability
- ✓ Color

Results

Physicochemical Properties of Orange Wastes Powder

Component	g/100 g DM	
Protein	13.25 ± 0.11	
Lipid	2.12 ± 0.05	
Ash	4.25 ± 0.07	
Carbohydrate	80.38	
Total dietary fiber	65.7 ± 0.9	
Insoluble dietary fiber	48.9 ± 0.5	
Soluble dietary fiber	16.8 ± 0.8	
Moisture content (g water/100 g DM)	8.52	
Water - holding capacity (g water/g DM)	Sieving (Din 60-70)	No sieving
	9.65	12.07

Extraction and Encapsulation Yield by Ultrasound-Assisted and Spray Drying Method

Optimum conditions for maximum extraction yield

Solvent	T (°C)	A (%)	t (min)	Pulse (sec/sec)	L/P
Water	35	40	10	7/6	32/1

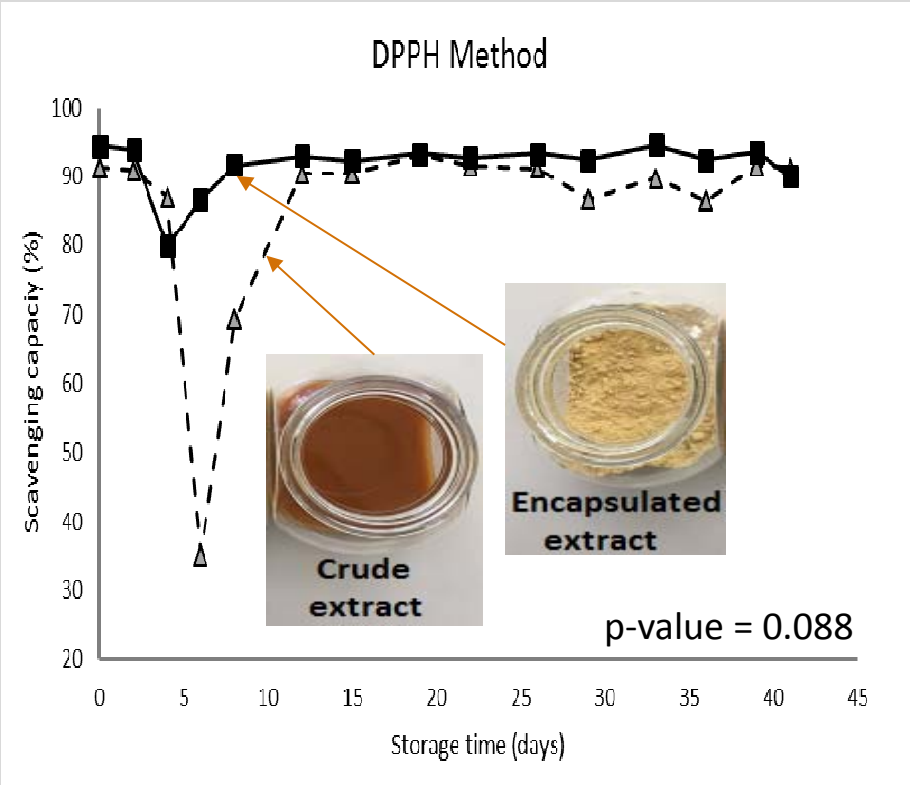
Yield: 13.85 mg GAE/g DM

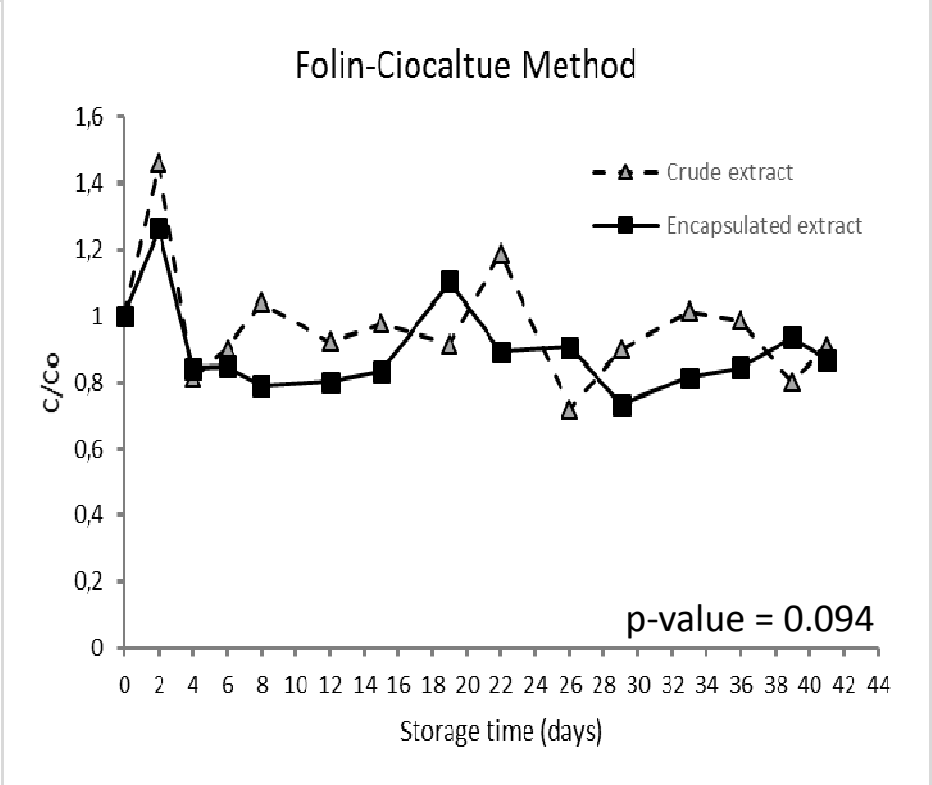
Optimum conditions for maximum encapsulation yield

Wall material	T (°C)	Q_a (%)	Q_s (m^3/h)	w/c
Orange wastes powder	162	50	0.80	9/1

Yield: 12.96%

Storage Stability of Crude and Encapsulated Extract



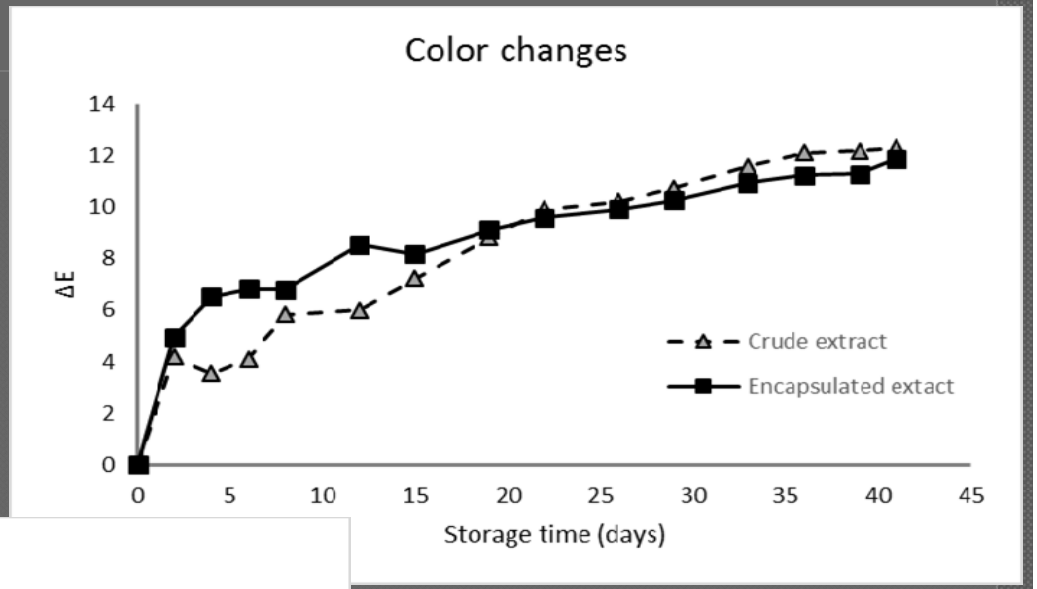


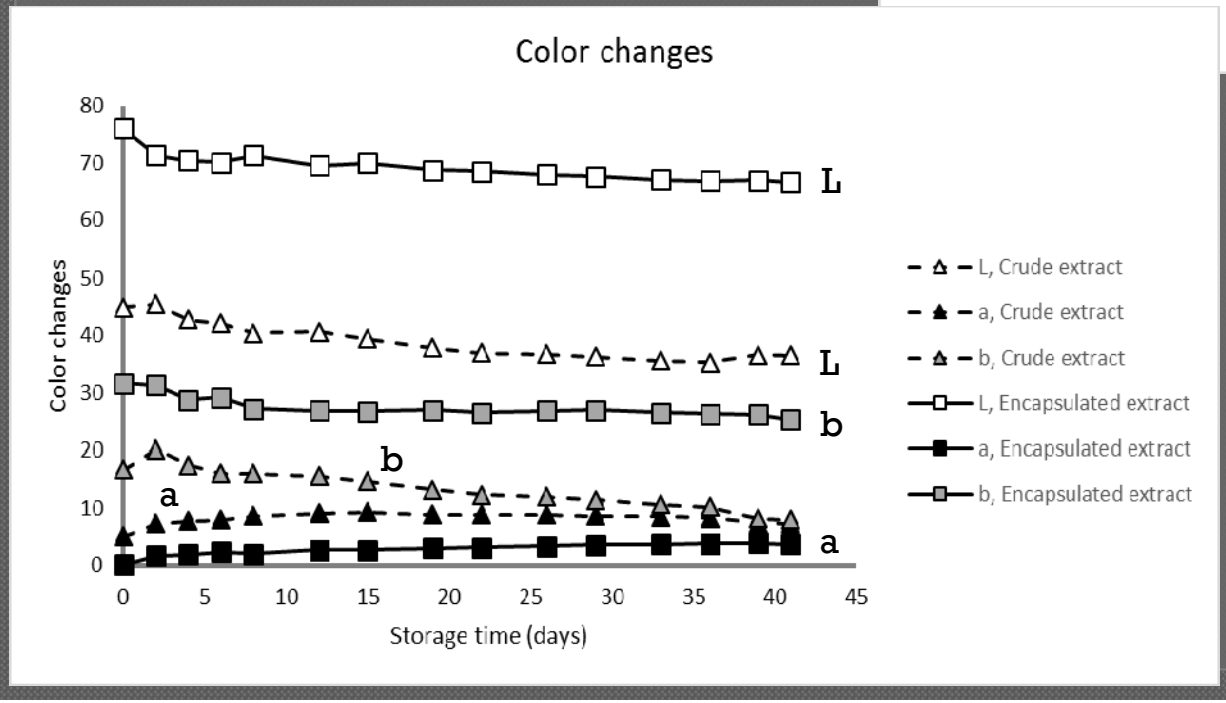
ANTIOXIDANT ACTIVITY **TOTAL PHENOLICS CONTENT**

Shelf-life test at 60°C for 40 days

Storage Stability of Crude and Encapsulated Extract

Encapsulated extract Crude extract



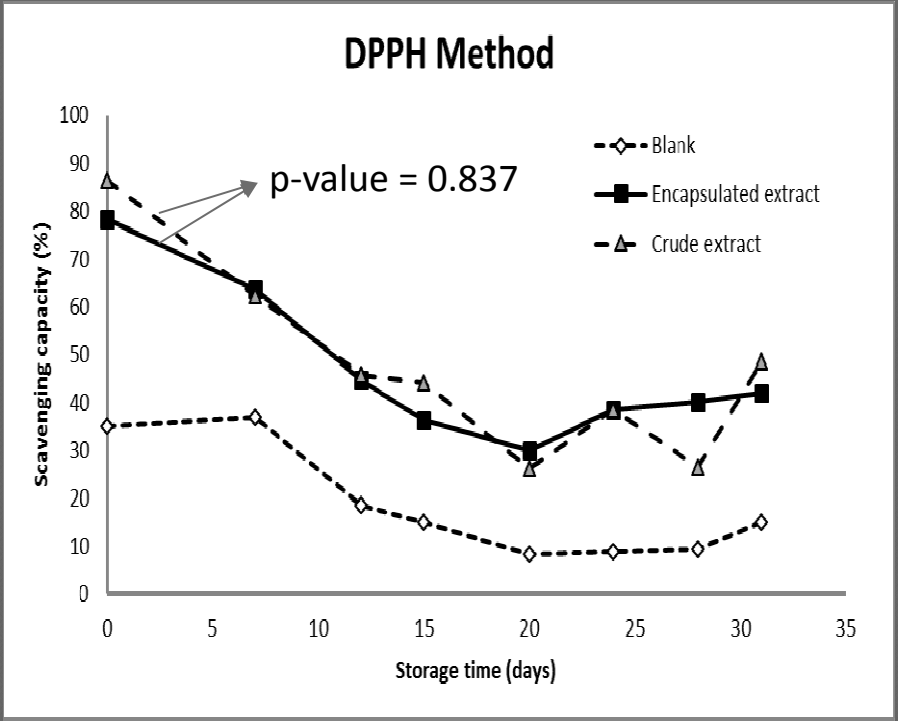


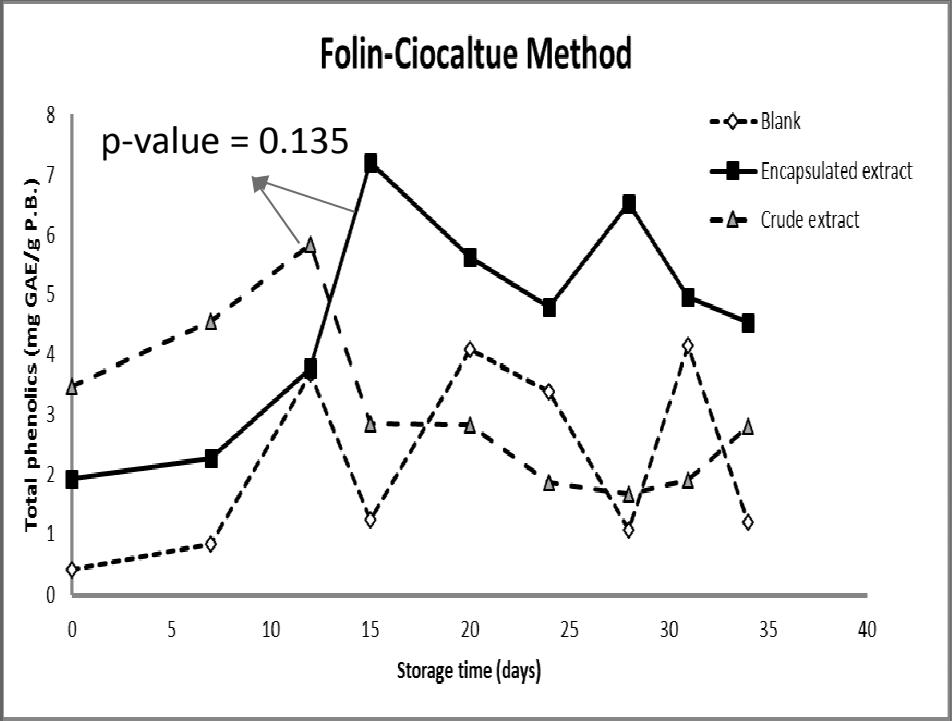
L: lightness

a: (+) red (-) green

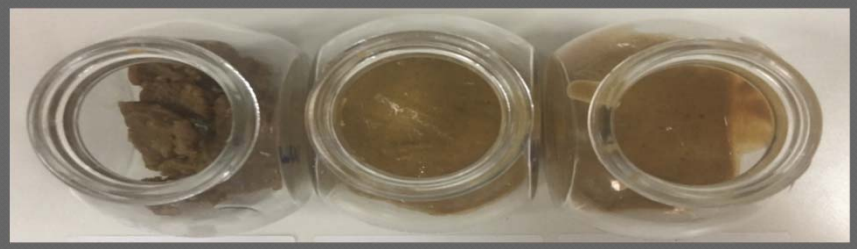
b: (+) yellow (-) blue

Antioxidant Capacity and Total Phenolics Content of Peanut Butter





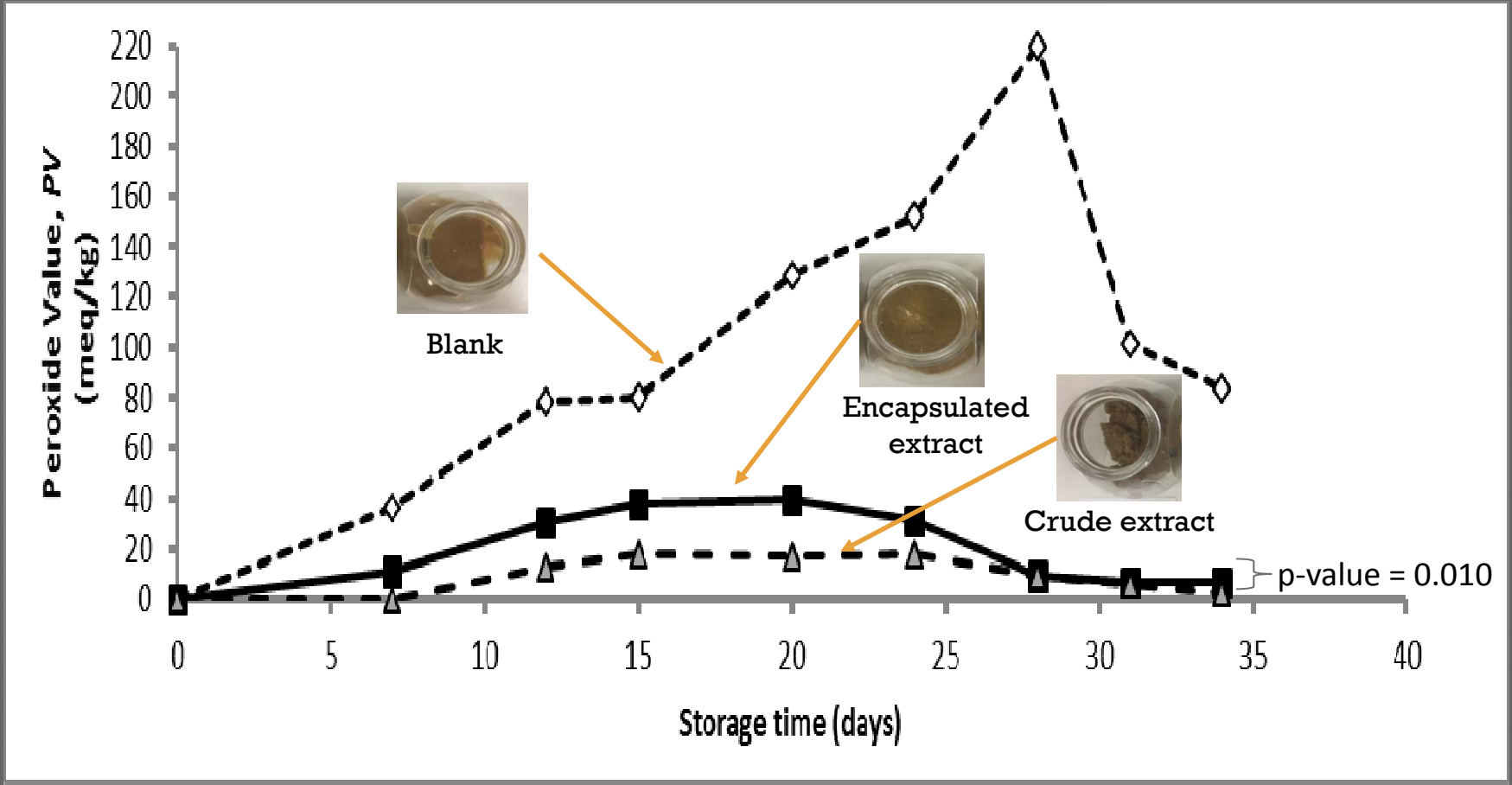
ANTIOXIDANT ACTIVITY **TOTAL PHENOLICS CONTENT**



Crude extract Encapsulated extract Blank

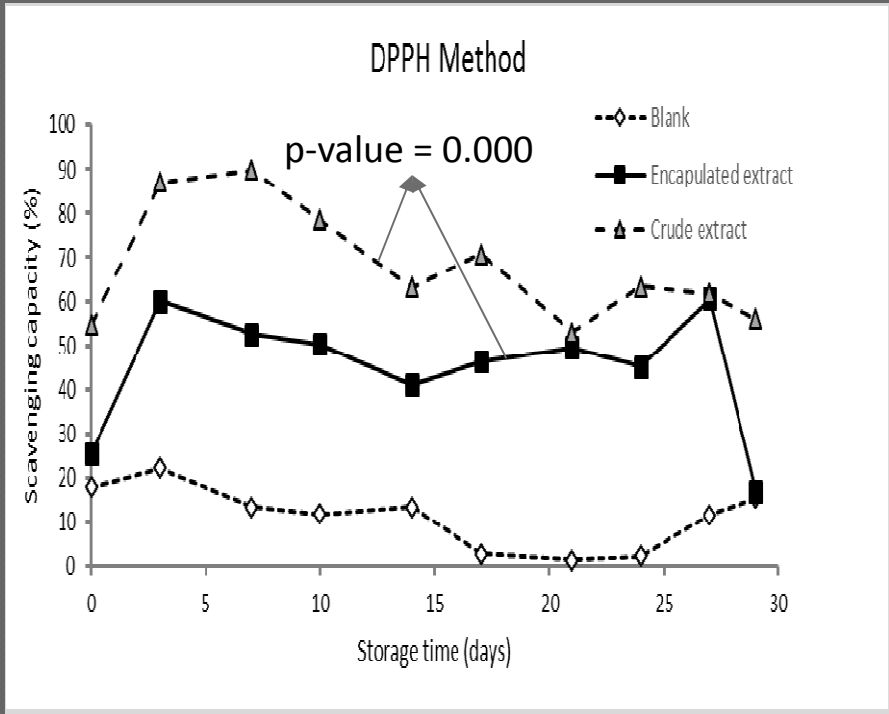
Shelf-life test at 60°C for 30 days

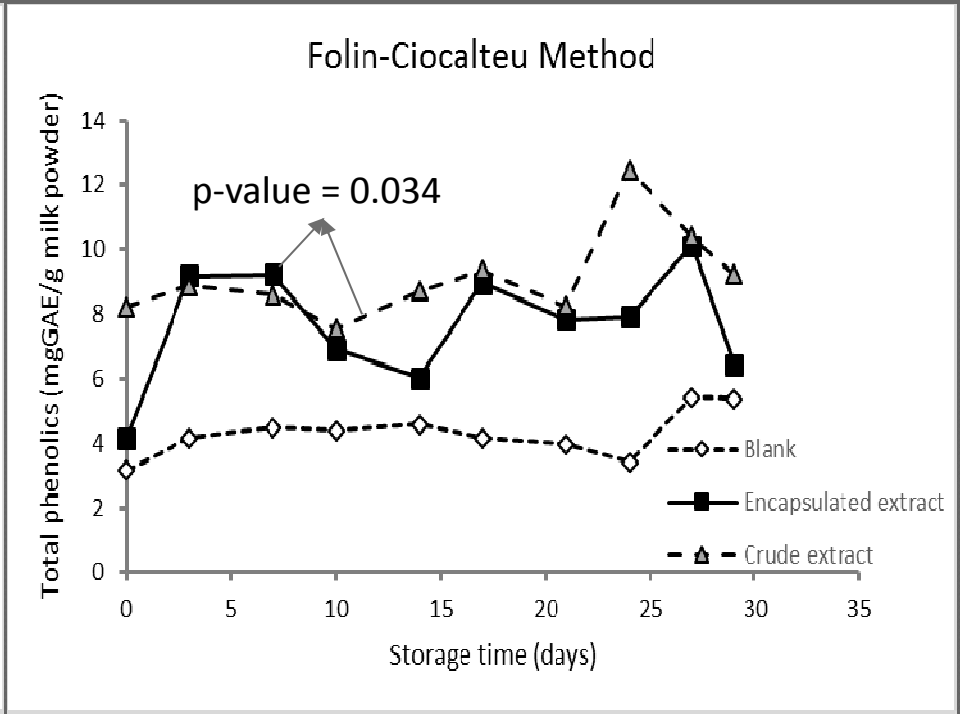
Effect of Pomegranate Peel Extract on Oxidative Deterioration of Peanut Butter



Shelf-life test at 60°C for 30 days

Antioxidant Capacity and Total Phenolics Content of Milk Powder



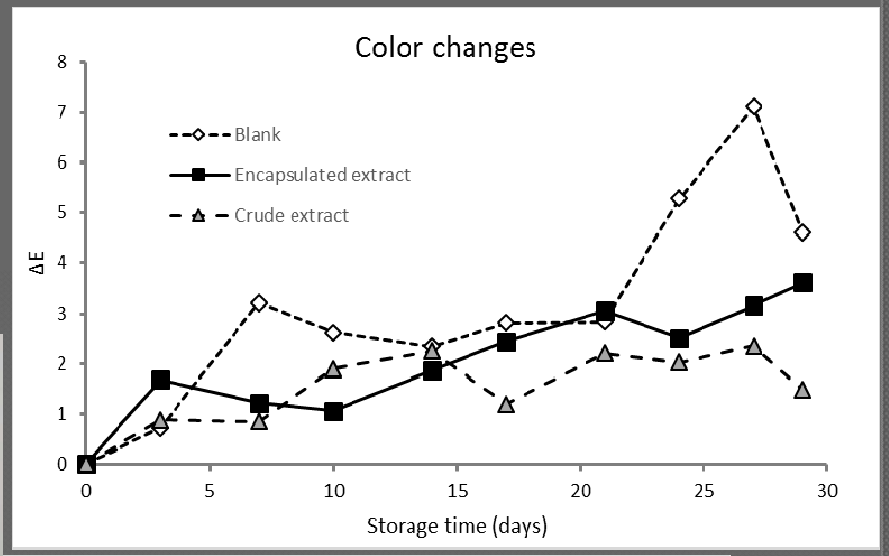


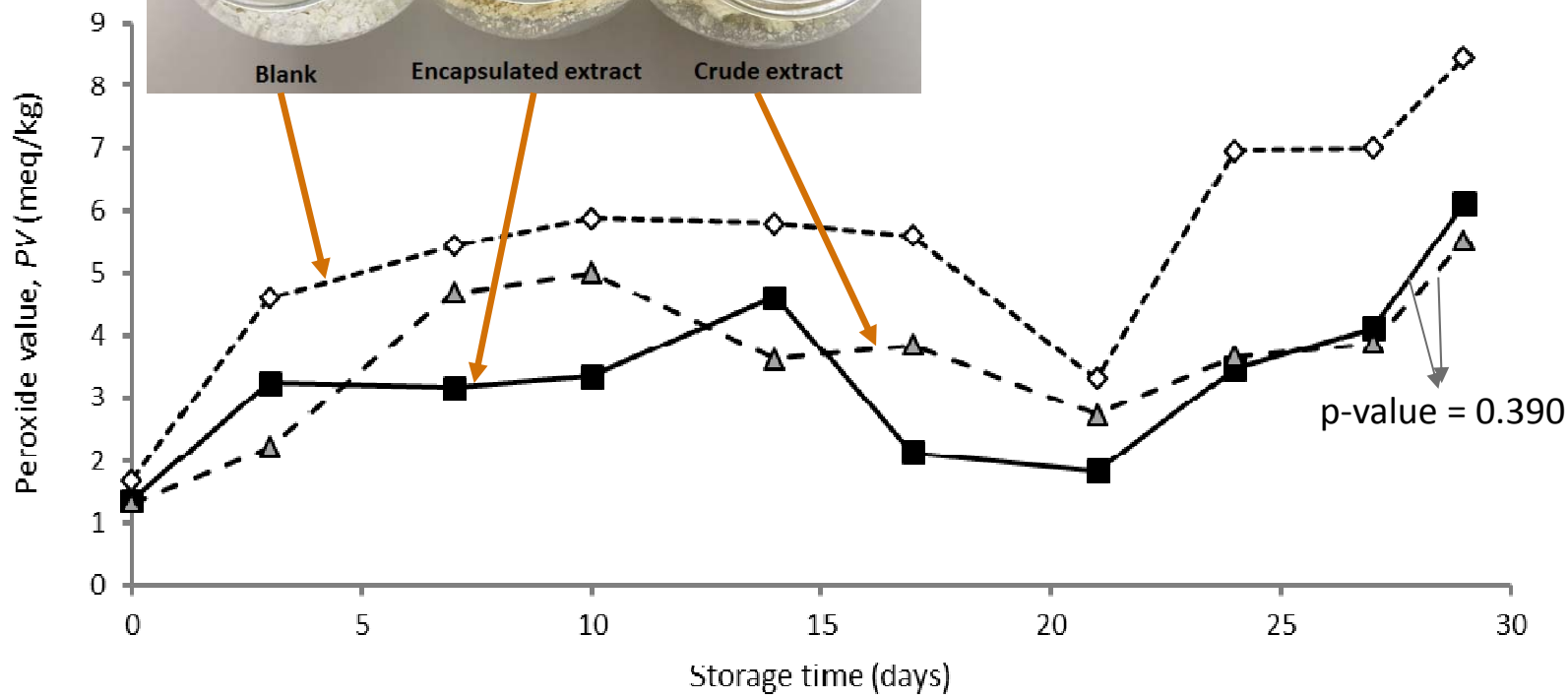
ANTIOXIDANT ACTIVITY **TOTAL PHENOLICS CONTENT**

Blank Encapsulated extract Crude extract

Shelf-life test at 60°C for 30 days

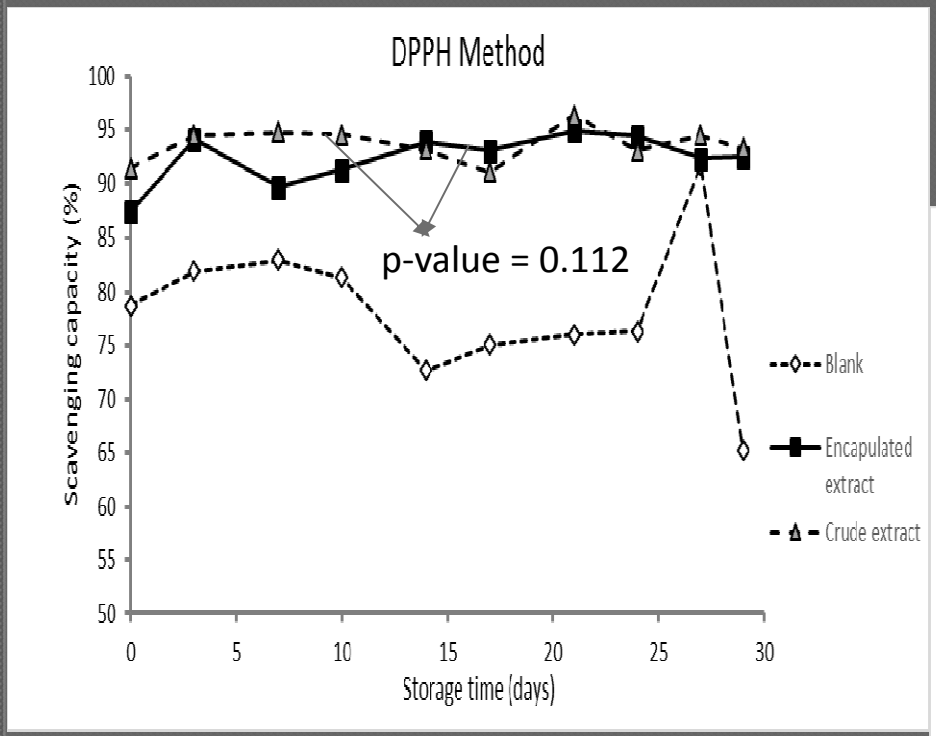
Effect of Pomegranate Peel Extract on Oxidative Deterioration of Milk Powder



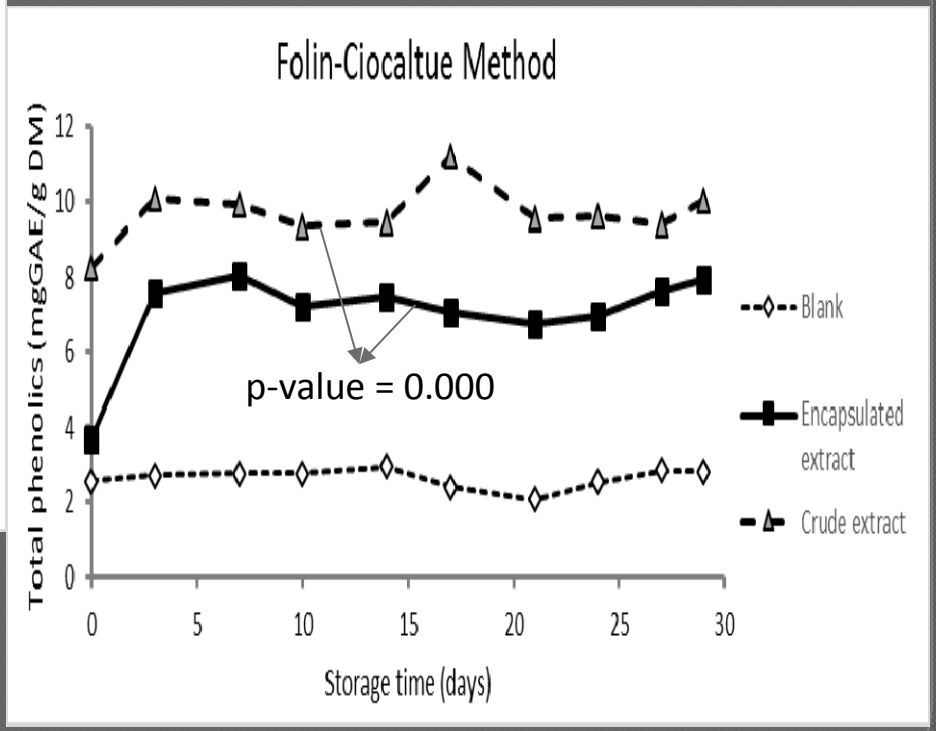


Antioxidant Capacity and Total Phenolics Content of Fresh Juice

Blank | Crude extract | Encapsulated extract



ANTIOXIDANT ACTIVITY



TOTAL PHENOLICS CONTENT

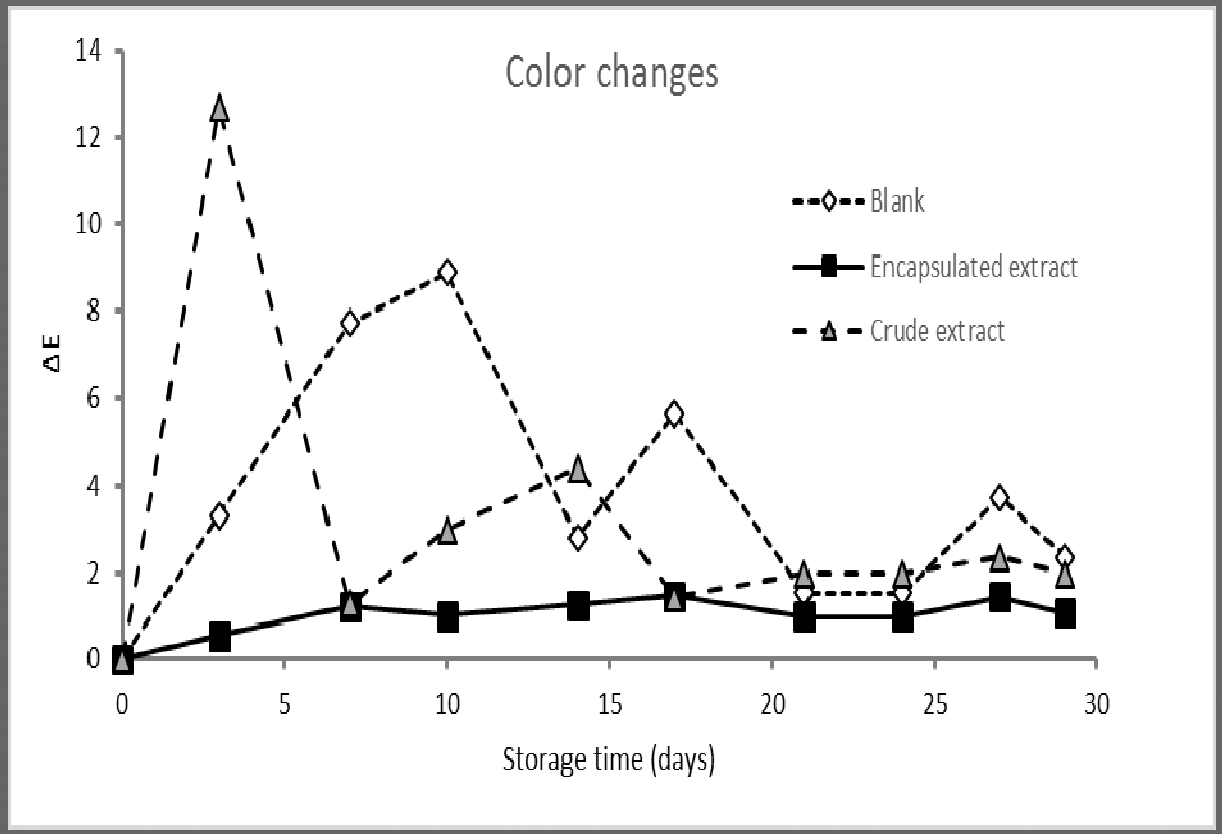
Shelf-life test at 4°C for 30 days

Color Changes of Fresh Juice

Blank

Crude extract

Encapsulated extract



Shelf-life test at 4°C for 30 days

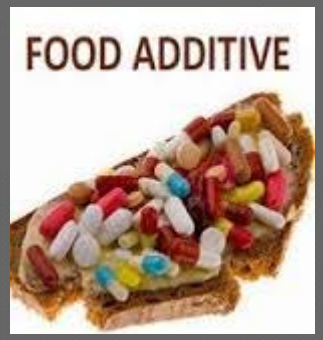
Conclusions

An integrated approach for utilization of pomegranate peels is suggested based on the spray drying encapsulation of their phenolics compounds using an alternative wall material (orange wastes)

- The orange wastes were successfully used as wall material for encapsulation of pomegranate peels extract
- During storage of crude and encapsulated extract there was no significant change at total phenolics content and scavenging capacity
- The extract (crude and encapsulated) was found efficient in improving the shelf-life of peanut butter, milk powder and fresh juice
- The crude extract changed the texture and the color of peanut butter significantly

Phenolics

Fibers



Thank you!