Physicochemical properties of oil-in-water emulsions applicable to beverages and edible films

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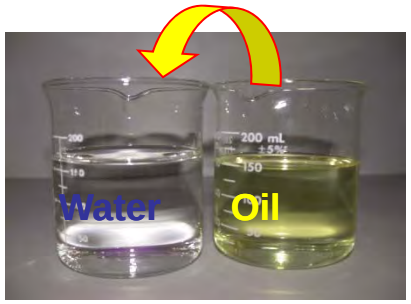
Cost Action FA-1001

3 June 2014

emulsion applications



beverage emulsions

provide flavour

provide turbidity

deliver functional ingredients

film forming emulsions

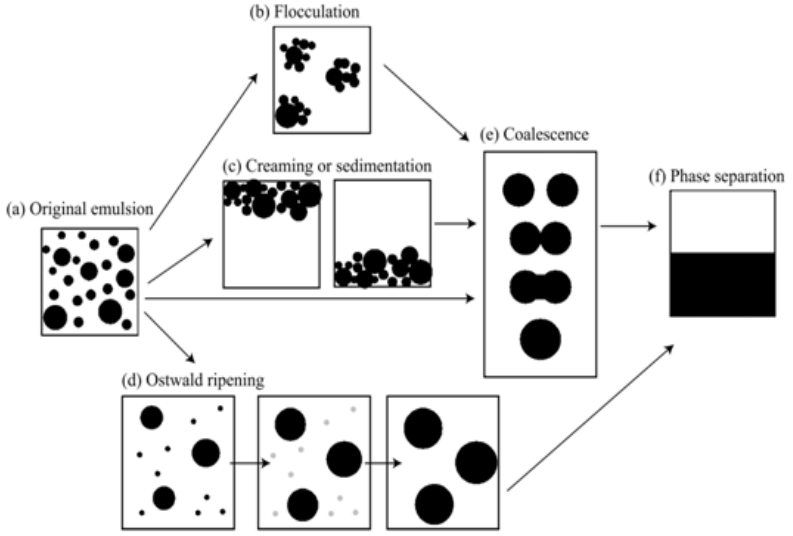
edible coatings

emulsion destabilization

emulsions are unstable systems which tend to break down

Emulsions destabilization (Dikinson, 1992; Waldtra, 1993; McClements,2005)

- gravitational separation
- flocculation
- coalescence
- ostwald ripening



(Adopted from Lopetinsky et al., 2006)

objectives of research

Part I. **Optimize physical properties** of orange oil-in-water **beverage emulsions** using response surface methodology

Part II. Examine **flavour release** in orange beverage emulsions

Part III. Examine **physical properties** of film-forming emulsions and **edible films**

Part I. Physical properties of orange oil-in-water beverage emulsions using response surface methodology

materials

Arabic gum
(6.8-12.7 g/100g)
emulsifier

Tragacanth gum
(0.1-0.3 g/100g)
stabilizer

Potassium sorbate (0.1 g/100g)
preservative

Sodium benzoate (0.1g/100g)
preservative

Water phase

di-Sodium hydrogen phosphate (1g/100g)
buffering agent

Citric acid (1.3g/100g)
acidifier

Oil phase

Orange oil (10.0-15.0 g/100g)
flavouring agent

Ester gum (10.0-15.0 g/100g)
density adjuster

preparation of emulsions

preparing water phase

mixing **stabilizer**, **emulsifier** and preservatives with buffer solution in 2 different parts and give 24 hour for complete hydration

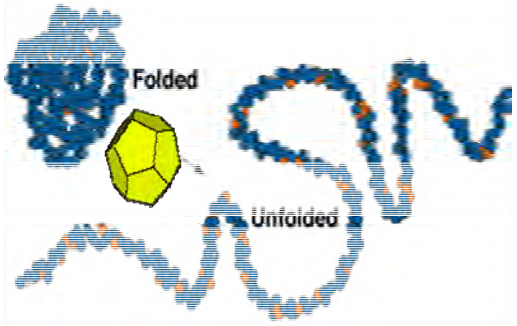
preparing oil phase

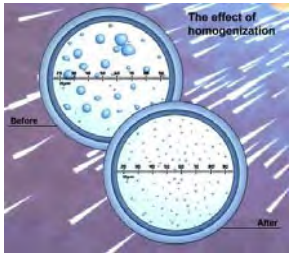
mixing orange oil with ester gum

adding oil phase to **emulsifier solution** and mix with high speed blender (pre-homogenization)

adding **stabilizer solution** and mix with high speed blender

homogenization with high pressure homogenizer (300 bar)





experimental design

2^3 full factorial design

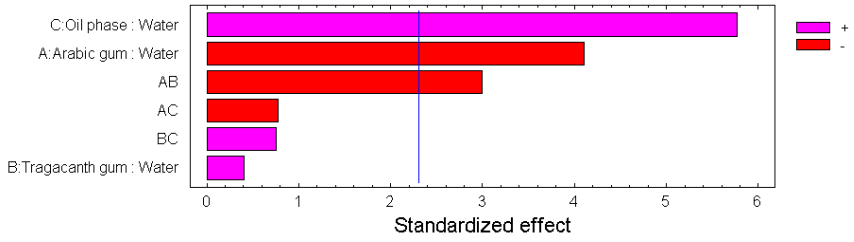
Independent variables	Symbol	Code levels		
		-1	0	+1
Arabic Gum: Water	A	6: 73.4	9: 64.35	12: 55.33
Tragacanth: Water	B	0.1: 73.4	0.2:64.35	0.3:55.33
Oil phase: Water	C	18: 73.4	24: 64.35	30: 55.33

methods

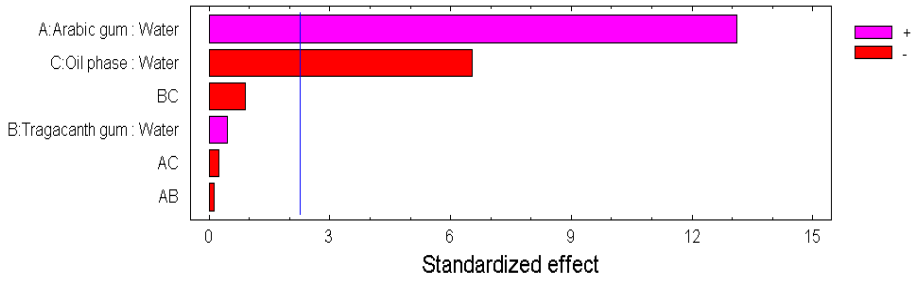
- Densitometer, Anton Paar
- Mastersizer, Zetasizer Malvern
- Rheometer CVO, Bohlin
- Spectrophotometer, Shimadzu
- Tensiometer Easy Dyne, Krüss

results

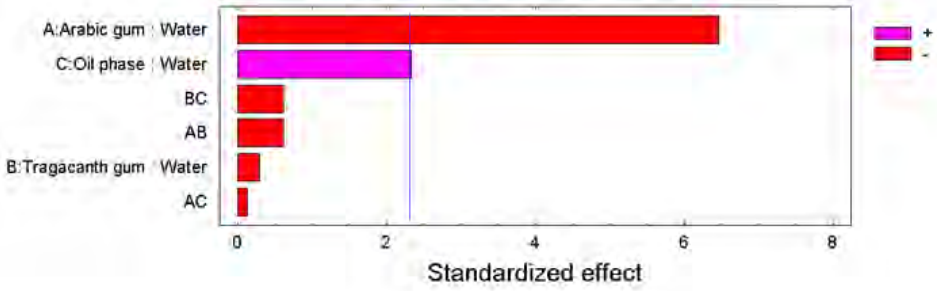
turbidity



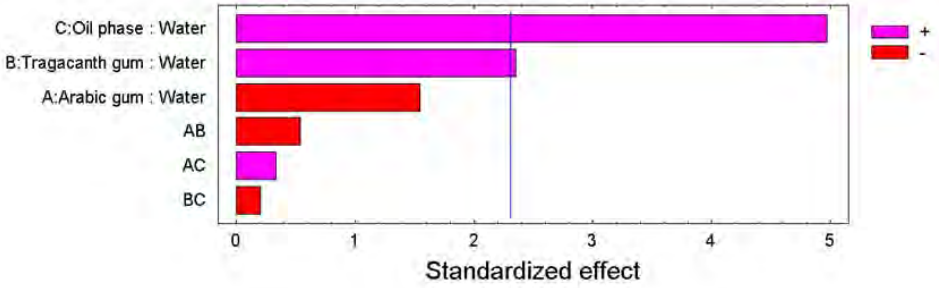
specific gravity



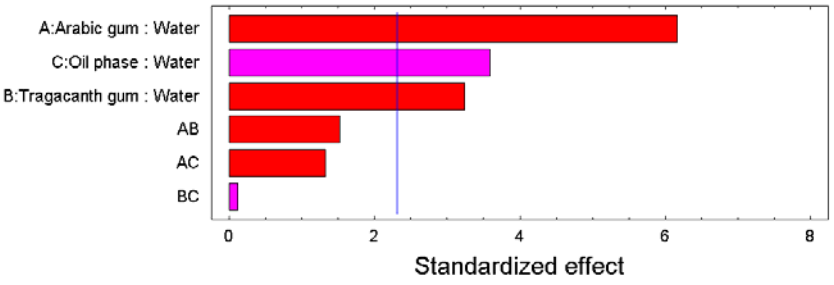
surface tension



mean particle size



zeta potential

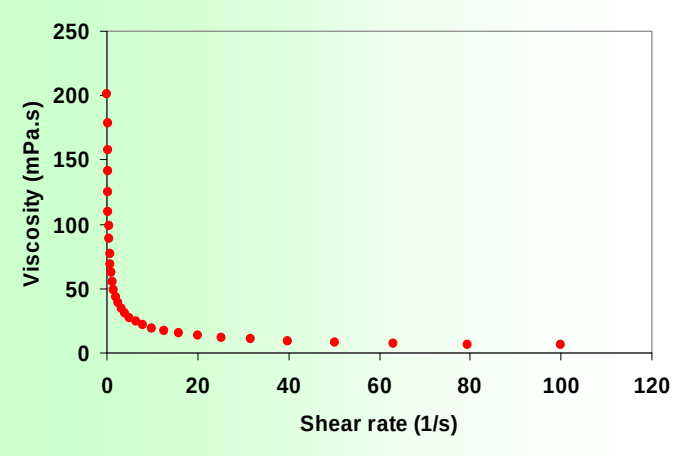


- **arabic gum increased the density** of the **oil droplets** through **steric stabilization** and **reduced the surface tension** between water and oil, hence, **increasing the stability** of emulsions

- only in 2 samples **(with low amount of arabic gum) aggregation** was observed

results

flow curves were fit to power law model:



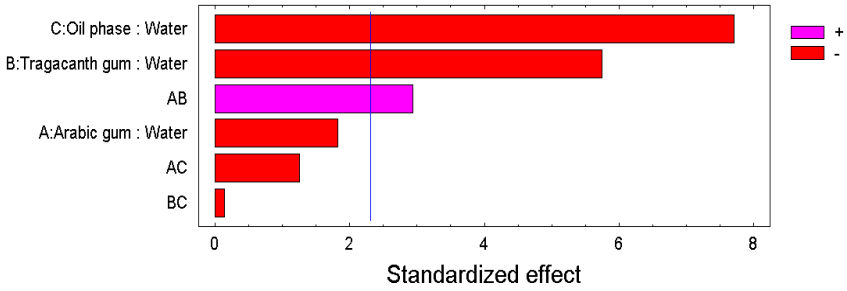
$$\eta = \mathrm{m}\,\dot{\gamma}^{(n-1)}$$

flow behavior index

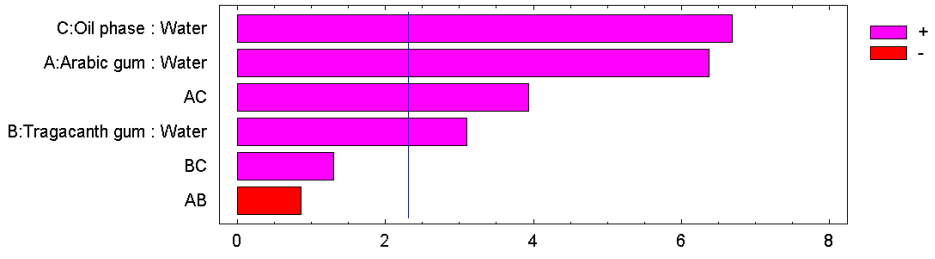
n=1 Newtonian

n<1 Shear thinning

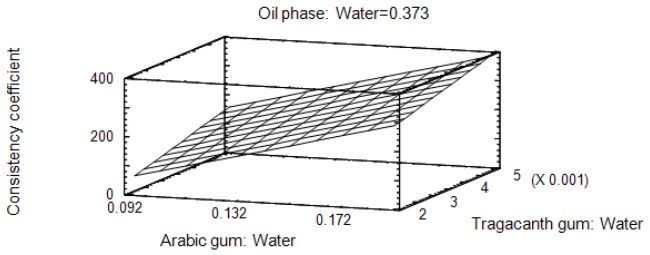
flow behaviour index "**n**"



consistency coefficient "**m**"



all emulsions showed **shear thinning behavior** which is desired by industrial production

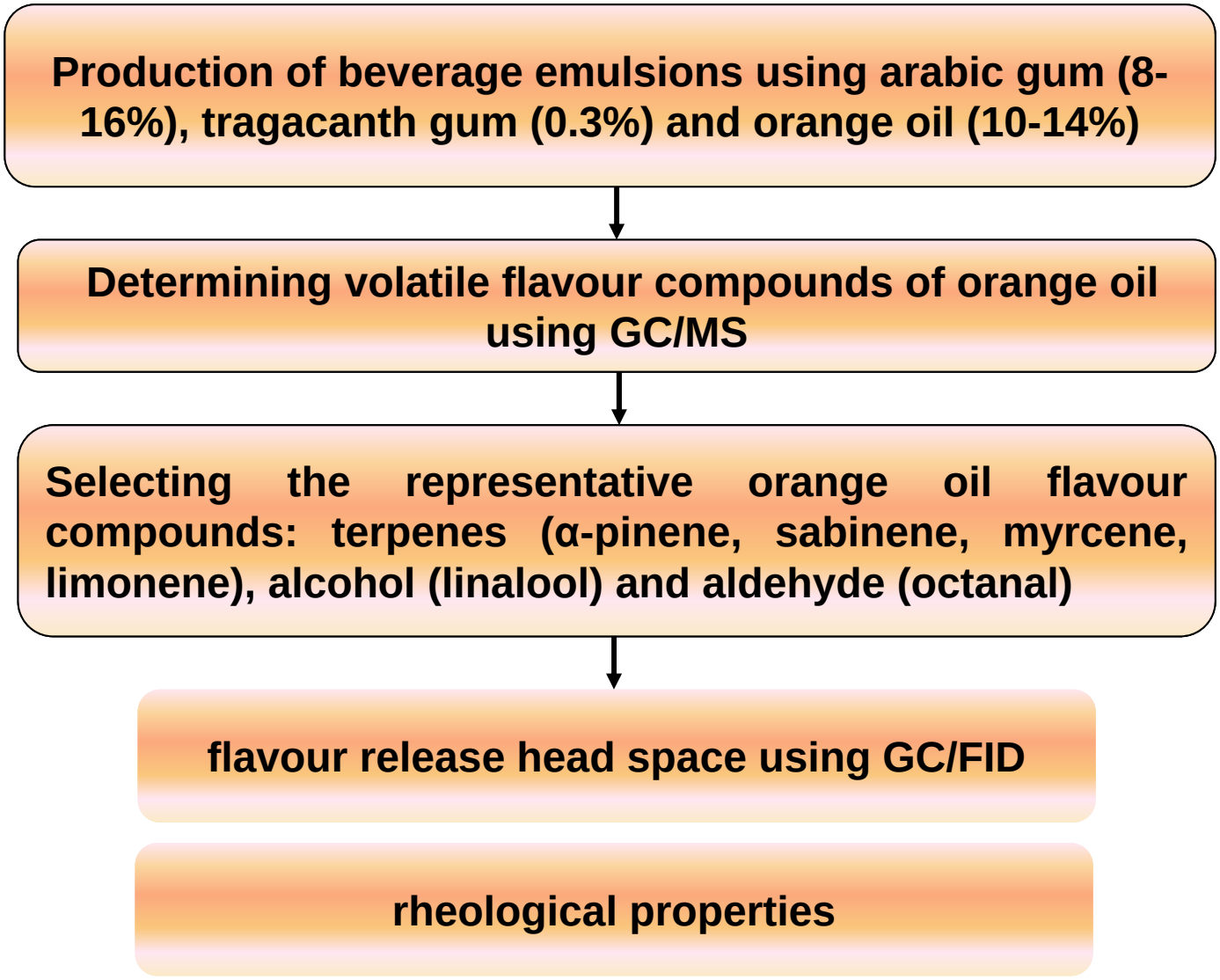


Part II. Flavour release in orange beverage emulsions

Objectives

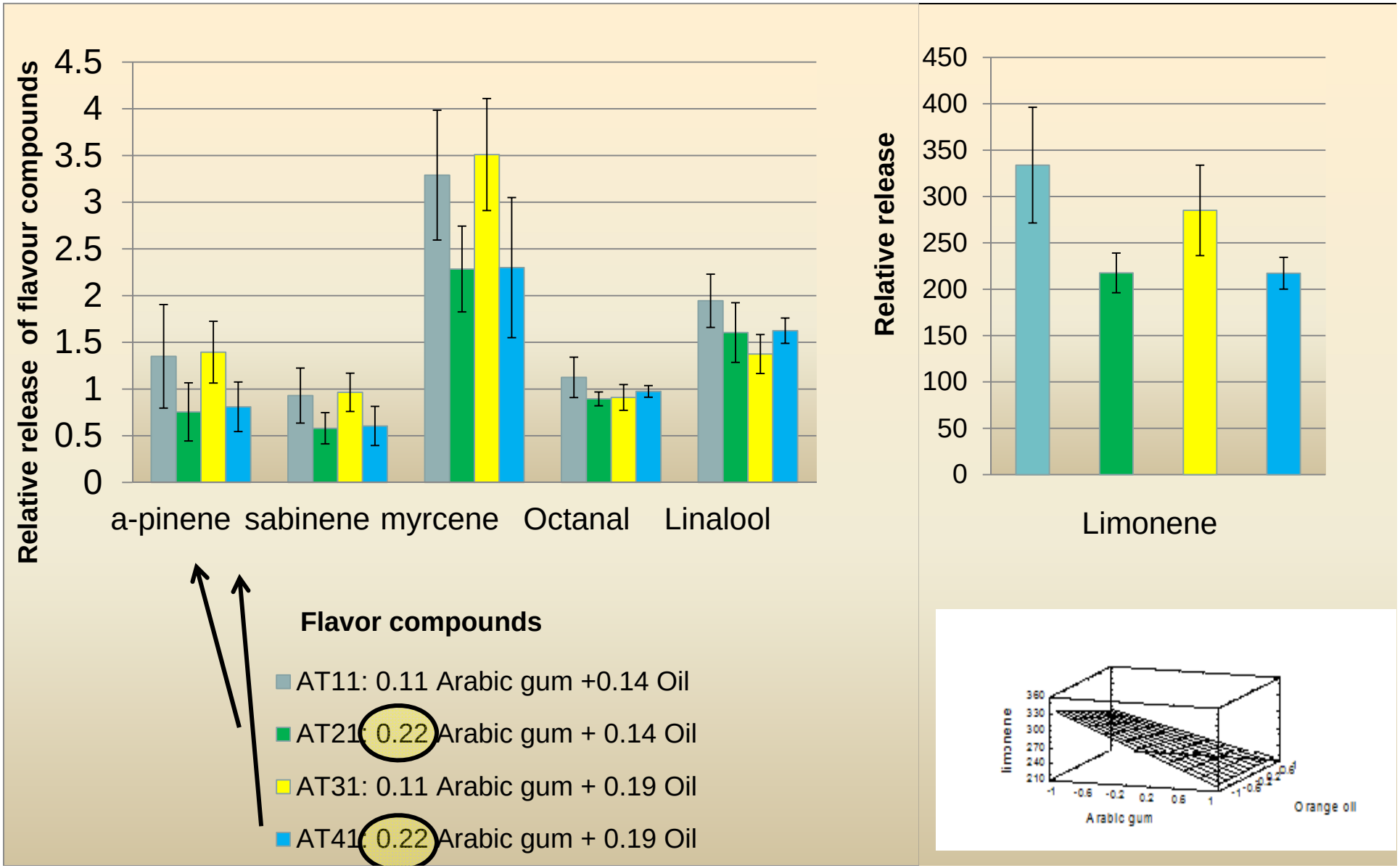
- To quantify the effect of arabic gum and orange oil on:
  - release behaviour of orange oil volatile compounds from beverage emulsions.
  - flow rheological properties
- To investigate the relation between flavour release and viscosity

research plan



results

Relative release of flavour compounds



conclusion part II

- **Flavour release mechanism could be controlled by arabic gum** and is more effective on monoterpenes

- **During the transfer of monoterpene hydrocarbons from oil phase, the protein segment of arabic gum acts as a barrier at the interface and decreased the flavor release**

- **Negative correlation was observed between consistency coefficient and flavour release - increasing viscosity reduces the diffusion of flavour molecules from water phase to vapour phase**

Part III. Physical properties of sodium caseinate based film-forming emulsions and edible films

Following the selection of sodium caseinate as the most suitable structural component of film-forming emulsions and edible films beside calcium caseinate, chitosan and cellulose

suitable concentrations as well as the proper type of lipid and plasticizers were determined.

materials and methods

Mixing De-Ionized water and sodium caseinate, then adding glycerol and Tween 80 and warming up the solution to 85°c

↓

Addition of melted stearic acid and corn oil while solution is mixing

↓

Homogenizing pre-emulsion with ultra-Turrax at 13000 rpm for 1 min followed by 24000rpm for 5 min

↓

Applying vacuum in order to remove air bubble

↓

Pouring 10 ml of film-forming emulsion in petridish

↓

Drying the films in controlled chamber (25°c and RH=50%) for 24 hours

Film-forming emulsions

- Rheological properties
- Surface tension

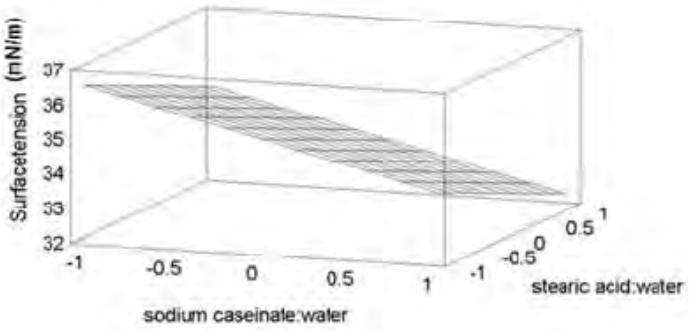
Edible Films

- Water loss during drying
- Water vapour permeability (WVP)
- Mechanical properties

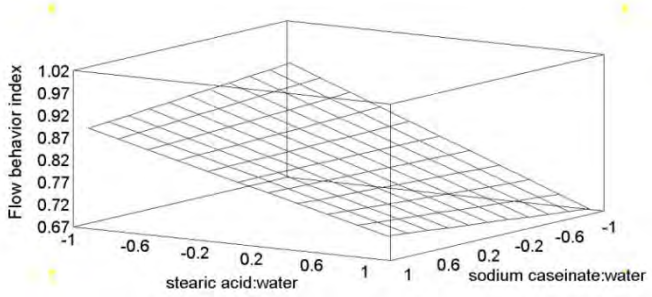
Code of experiment	X1	X2	Sodium caseinate (g/100g)	Stearic acid (g/100g)	Water (g/100g)
CF1	-1(6:86)	-1 (0)	6.13	0.00	87.87
CF2	+1 (8:86)	-1 (0)	8.00	0.00	86.00
CF3	-1 (6:86)	+1 (2:86)	6.00	2.00	86.00
CF4	+1 (8:86)	+1 (2:86)	7.83	1.96	84.21
CF5	0 (7:86)	0 (1:86)	7.00	1.00	86.00

All samples contain 1.5 g/100 g corn oil, 2.5 g/100g glycerol and 2 g/100 g Tween 80

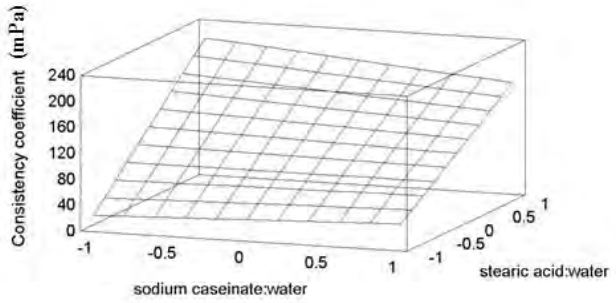
results



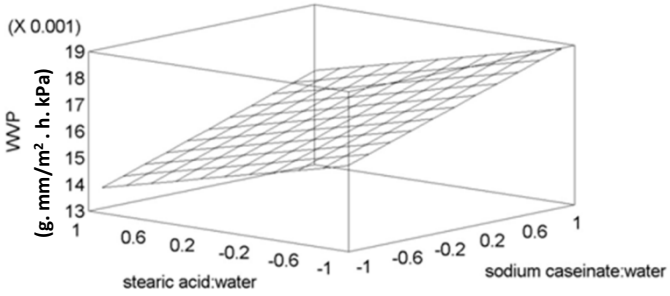
Surface tension = 34.4 - 1.2 X_1 - 0.88 X_2



Flow behavior index = 0.804 + 0.001 X_1 - 0.106X_2 + 0.0213 X_1X_2



Consistency coefficient = 112.9 - 5.5 X_1 + 82.0 X_2- 14.1 X_1X_2



WVP = 0.0164 + 0.0013 X_1 - 0.0011 X_2

X_1= Sodium caseinate: Water

X_2= Stearic acid: Water

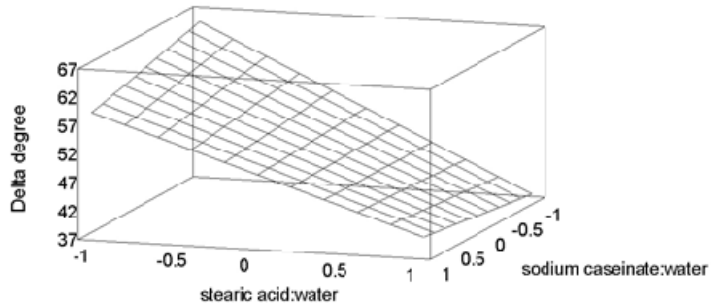
results: viscoelastic properties

δ

90º Purely Viscous ⟷ **0º Purely Elastic**

$$\delta = G''/G'$$

Viscous (loss) modulus **Elastic (storage) modulus**

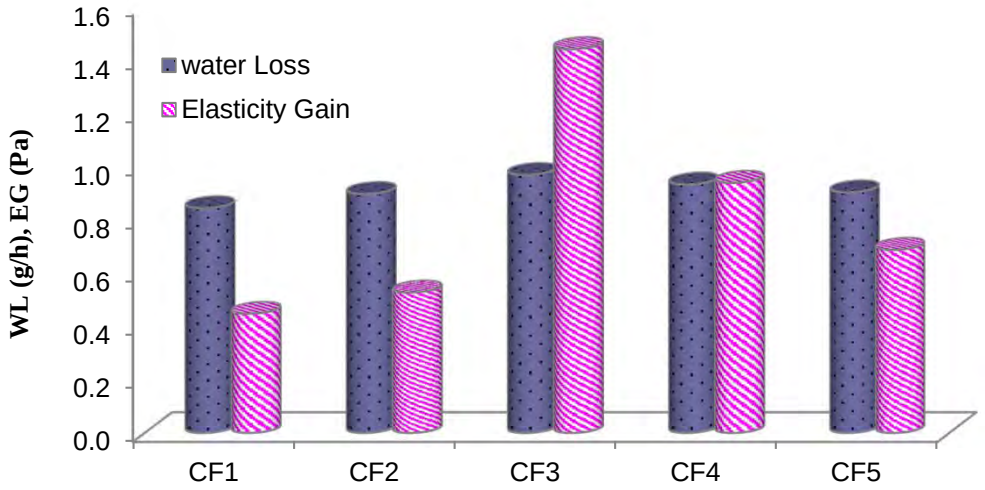


$$\delta = 50.5 - 0.71\,X_1 - 11.4X_2 + 2.1\,X_1X_2$$

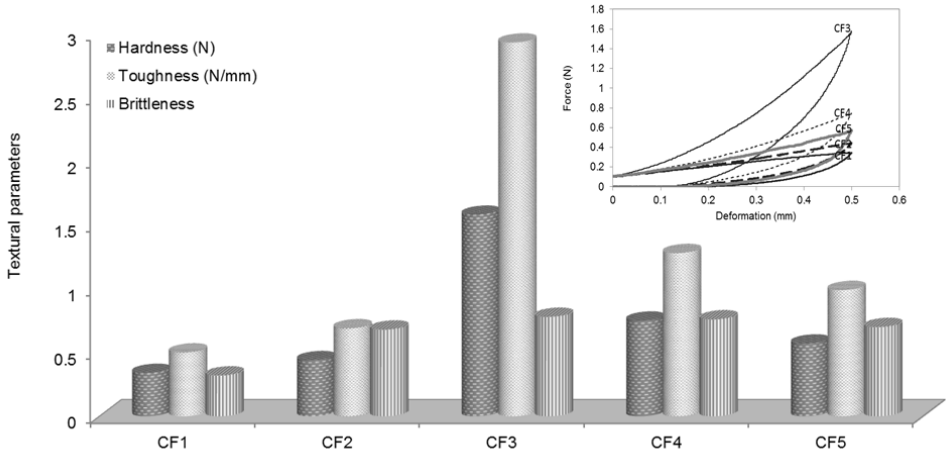
X_1= Sodium caseinate: Water

X_2= Stearic acid: Water

results of films after 3h drying



Stearic acid (CF3,4,5) increase the rate of water loss and elastic modulus during drying



solid lipid aggregation of steraic acid form a more rigid dispersed phase in the film and reduce its ability to stretch

conclusion part III

- The incorporation of lipids into hydrophilic protein-based films allows the modification of their barrier properties.

- The increase of the ratio of sodium caseinate to water decreases the surface tension significantly due to the nature of this protein.

- Stearic acid, due to its hydrophobicity and chain length, is able to reduce water vapor permeability and could also increase the rate of water loss and elastic modulus during drying giving less flexible and extensible films.

concluding remarks

- All the oil-in water emulsion have shear thining behaviour which is desired by industries because the droplets are preventing from creaming but still flow easily when poured or pumped.
- **Tragacanth gum** was found to be an excellent stabilizer. This gum could be a suitable alternative to replace density adjuster which have limited levels of use due to their health disadvantages.
- Use of **arabic gum** in the beverage emulsions should be taken into consideration to minimize flavour release.
- The rheological characteristics of film forming **emulsion** and mechanical attributes of edible film were correlated.

acknowledgements

University of Natural Resources and Life Sciences, Vienna, Department of Food Science and Technology

Esarom GmbH

Food Research and Development Center, Agriculture and Agri-Food Canada

Österreichische Orient-Gesellschaft Hammer-Purgstall

Cost Action FA-1001

acknowledgement

Gerhard Schleining

Matthias Schreiner

Ali R. Taherian

Gülsah Sümen

Nazli Khorsand

Thanks for your kind attention!

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