

*From:* essentiaproteins.com

# **Emulsion gel**: Cost-efficient technology to strengthen competitiveness of meat products

# **เจลอิมัลชัน**: เทคโนโลยีคุ้มค่าเพื่อเสริมสร้างขีดความสามารถในการแข่งขันของผลิตภัณฑ์เนื้อสัตว์

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Department of Product Development
Faculty of Agro-Industry, Kasetsart University



***From***: http://ionmos.eu/en/products/meat-products/

# AGENDA



***From:*** southsidemarket.com/products/garlic-smoked-sausage-wholesale

**I. เจลอิมัลชันต่อการพัฒนาความคงตัวของผลิตภัณฑ์เนื้อสัตว์อิมัลชัน**

- ความคงตัวทางกายภาพ
- ความคงตัวทางเคมี

**II. เจลอิมัลชันต่อการพัฒนาคุณค่าทางโภชนาการของผลิตภัณฑ์เนื้อสัตว์อิมัลชัน**

- Fatty acid profile optimization
- Lipolysis control

**III. เจลอิมัลชัน: กลยุทธ์การปรับสูตรเพื่อเพิ่มความสามารถในการแข่งขัน**

**Keywords**
Emulsion gel; Emulsified meat products; Product development; Future food; Competitiveness

# Emulsified meat products

**the products made from finely chopped or comminuted meat combined with fat**

Bologna
Cocktail frankfurters
Frankfurters
Hot dogs
Vienna sausages

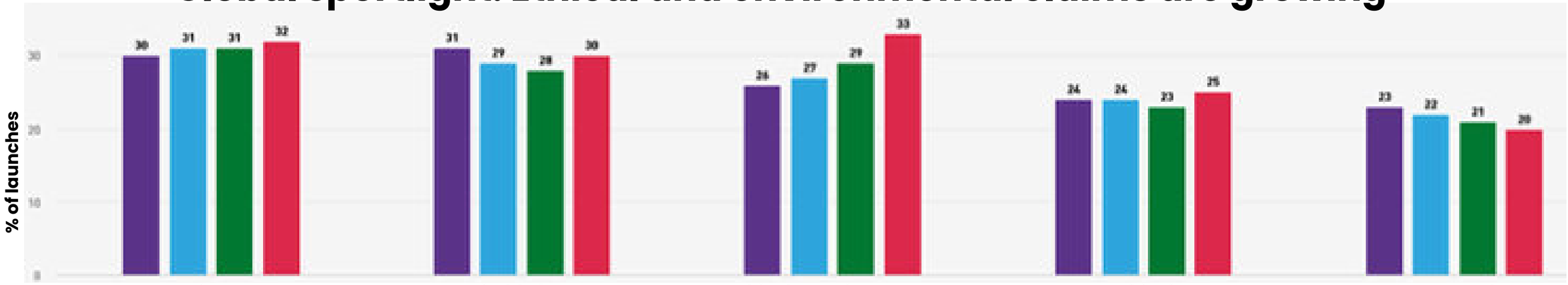


From: https://foodrepublic.com/1937024/all-natural-bologna-meat-does-it-exist



From: https://sausageman.co.uk/product/frankfurter-wurstchen-b2c.

## Global sportlight: Ethical and environmental claims are growing




**easy to use**

- ready-to-cook
- pre-cooked air fryer friendly foods
- microwaveable options

**high/added protein claim**
to convey value for money

- transparency around animal welfare
- local sourcing to minimise food waste
- sustainable packaging

**health friendly**
reduced sugar, fat, and sodium contents

**natural and organic foods**
to avoid substances like hormones and antibiotics

Source: Mintel GNPD, November 2021-October 2025

# Matrix of emulsified meat products

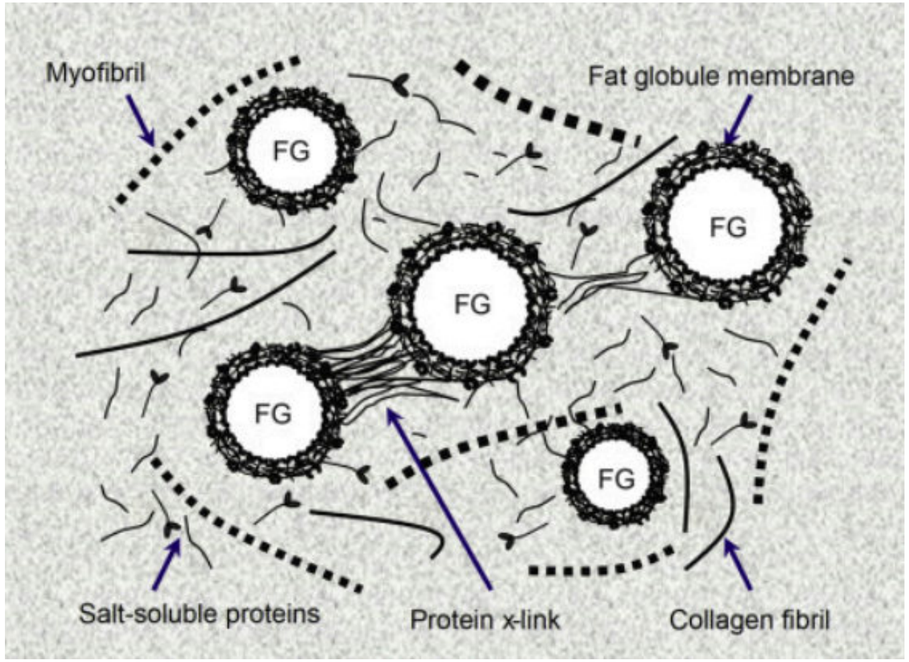



**Fig. 1** Schematic representation of a typical meat emulsion
*From:* Xiong (2024)

## Multiphasic system

- network of myofibrillar proteins, muscle fiber segments, and connective tissue components
- dispersed fat globules

myofibrillar proteins

↓

**emulsification**: distribute of fat globules

↓

**heating**: several transition

40-50 °C: denature of myosin >> gelation begin

60 °C: denature of collagen

72-83 °C:** denature of actin >> consolidate meat protein gel network

## Typical fat content in emulsified meat products: 20-30 %

fat globules within the protein matrix start melting
before the protein matrix gelation is completed

**loss of fluid >> loss of texture and flavor**

**Table 1** Final batter temperatures based on predominant fat source of the formula

| *Predominant source of fat* | *Final emulsion temperatures in °C (°F)* |
|---|---|
| Chicken or turkey | 7 °C (45 °F) |
| Pork | 12–15 °C (55–60 °F) |
| Beef | 4 °C (40 °F) or 18–24 °C (65–75 °F) |

***From:*** Knipe (2024)

- **control batter viscosity**
- **sufficient emulsifier**
- **stable interfacial protein film & protein matrix structure**

# Functional of animal fats

## typical melting points ca. 30–50 °C

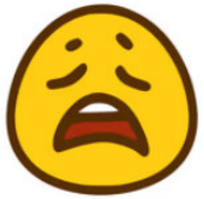
- **Viscosity control**
  >> enhance batter stability before complete gelation
- **Reduction of cooking loss**
  >> trap moisture and prevent excessive shrinkage or fluid loss when heated
- **Textural stability**
  >> fat globules act as physical fillers that strengthen the surrounding protein network
- **Juiciness and mouthfeel**
  >> melt during cooking to impart a smooth, lubricated texture and rich mouthfeel
- **Flavor release**
  >> act as a carrier for volatile flavor compounds

## important to quality & palatability of the products

**Table 2** Fatty acid composition of fats from muscles and adipose tissues of some animals

| กรดไขมัน | ไขมันที่แทรกตามกล้ามเนื้อ [1] | | | เนื้อเยื่อไขมัน [2] | | | |
|---|---|---|---|---|---|---|---|
| | หมู | โค | แกะ | หมู | โค | แกะ | ไก่ |
| ไมริสติก (14:0) | 1.3 | 2.7 | 3.3 | 1.30 | 2.93 | 2.65 | 0.89 |
| ปาล์มมิติก (16:0) | 23.2 | 25.0 | 22.2 | 20.66 | 24.52 | 20.73 | 28.36 |
| ปาล์มมิโตเลอิก (16:1 *n*-7) | 2.7 | 4.5 | 2.2 | 1.98 | 2.81 | 0.96 | 5.75 |
| สเตียริก (18:0) | 12.2 | 13.4 | 18.1 | 10.91 | 17.85 | 28.06 | 6.70 |
| โอเลอิก (18:1 *n*-9) | 32.8 | 36.1 | 32.5 | 39.13 | 38.63 | 33.94 | 41.12 |
| ลิโนเลอิก (18:2 *n*-6) | 14.2 | 2.4 | 2.7 | 19.56 | 1.84 | 1.36 | 14.32 |
| ALA (18:3 *n*-3) | 0.95 | 0.70 | 1.37 | 1.21 | 0.83 | 0.83 | 0.63 |
| อะราคิโดนิก (20:4 *n*-6) | 2.21 | 0.63 | 0.64 | *nr* | *nr* | *nr* | *nr* |
| EPA (20:5 *n*-3) | 0.31 | 0.28 | 0.45 | 0.12 | 0.06 | 0.15 | 0.09 |
| DHA (22:6 *n*-3) | *nr* | *nr* | *nr* | 0.20 | 0.20 | 0.19 | 0.07 |

*From*: นพรัตน์ ปราบสงบ (2564)



## Consumers' pain points

Animal fats always consist of **high SFA** and **cholesterol contents**, thereby increasing risk of health problems

## PUFAs rich oil inclusion

**low melting point as a liquid oil >> inferior product stability**

# Emulsion gel

**complex colloidal materials consisting of a three-dimensional network of gelator and embedded oil droplets**

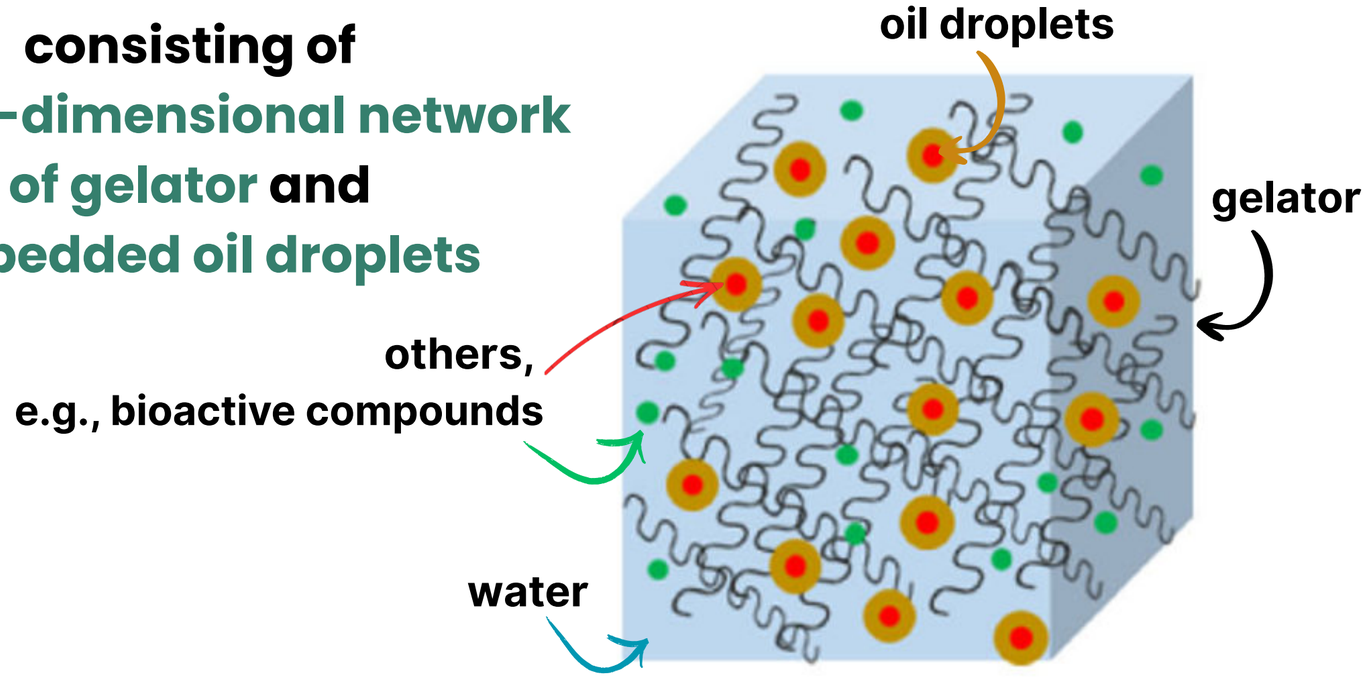



**Fig. 2** Schematic illustration of EG
***From:*** modified from Lu et al (2019)

## 1 Gelator

**Proteins**: *e.g.*, soy protein, zein, and egg white protein
**Polysaccharides:** *e.g.*, inulin, starch, and alginate

## 2 Oil phase

## 3 Others

- gel inducer

*e.g.*, citric acid and Ca-chloride

- surfactants:

*e.g.*, monoacylglycerol

- bioactive compounds



## Key Feature of EG

- soft solid structure
- viscoelastic property
- stable against mechanical force

**properly mimic physical behavior of solid fat while improving nutritive profile of food products**

- health-friendly gelator and oil composition
- compatible for both hydrophilic and lipophilic bioactive compounds

# Research trend of EG

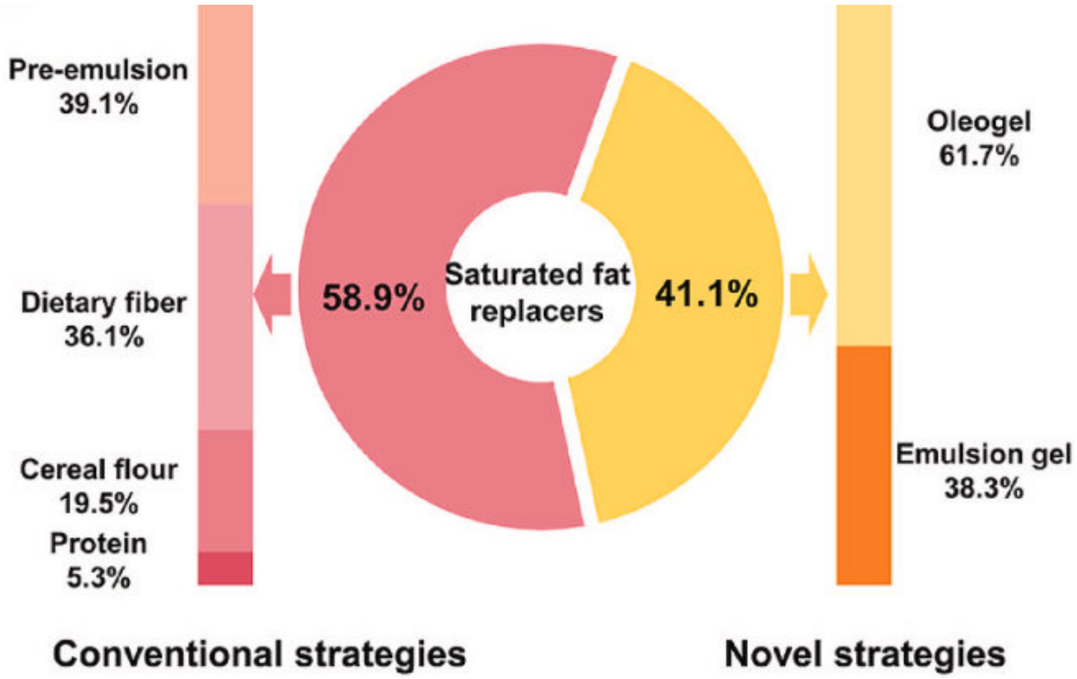



**Fig. 3** Trends of publications related to SFA replacement: Percentage of different strategies (2010-2022)
*From: modified from Guo et al.* (2023)

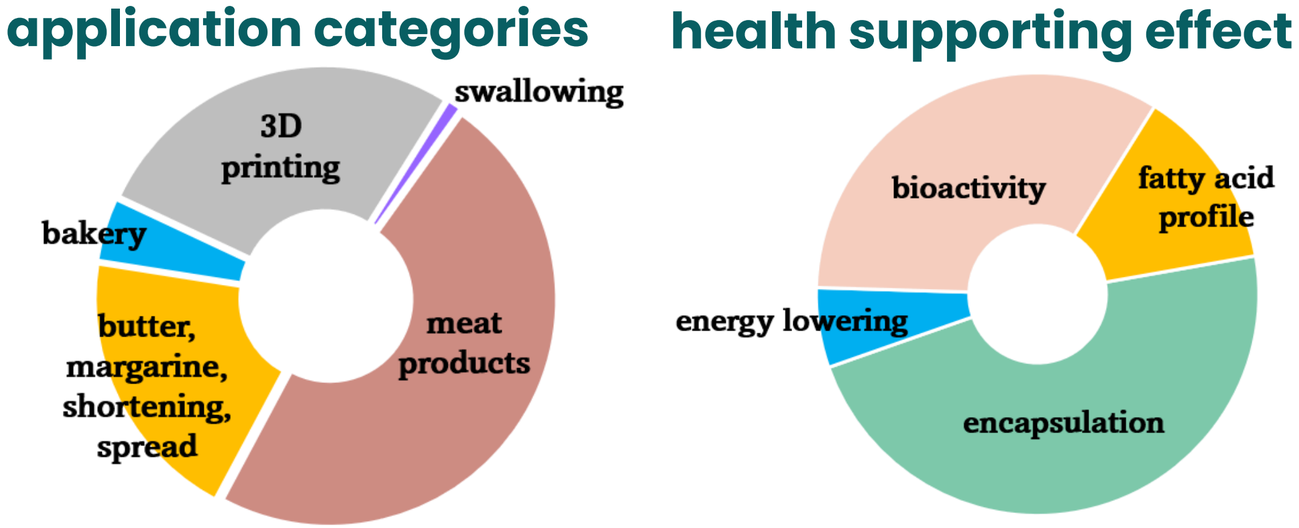



**Fig. 4** Trends of publications related to EG in foods

**Table 3** Patent family related to EG for food application

| Year | Patent families* | country | Application | Nutritional benefit |
|---|---|---|---|---|
| 2021 | ≥3 | China | fat replacer / functional carrier | low SFA, trans-free, bioactive delivery |
| **2022** | **≥8** | **China** | **meat / bakery / 3D–4D printing / general foods** | **fat reduction, low SFA, zero-trans, bioactive** |
| 2023 | ≥4 | | 3D printing / plant-based meat / bakery | fat replacement, low-fat, active compounds |
| 2024 | ≥5 | China | meat / mayonnaise / 3D printing / functional foods | low fat, bioactive, healthier oils |
| 2025 | ≥2 | China | meat / functional food | bioavailability, bioactive delivery |

*From*: ChatGPT (2026)

# Emulsion gel to maintain product stability

Contents lists available at ScienceDirect

Journal of Agriculture and Food Research

journal homepage: www.sciencedirect.com/journal/journal-of-agriculture-and-food-research

## Fabrication of soy protein isolate based emulsion gel loaded with rice bran oil as animal fat mimetic: Effect of transglutaminase on physical property of the emulsion gel and application in meatballs

Sorrayut Kerdlapee, Nopparat Prabsangob *

*Department of Product Development, Faculty of Agro-Industry, Kasetsart University, Bangkok, 10900, Thailand*

**INGREDIENT**

soy protein isolate (SPI): 3, 4.5, and 6 %
k-carrageenan (kCA)
soybean (oil fraction 0.50)
transglutaminase (TGase) 0, 1, and 2 %

**cold set gelation**

**KEY FEATURE**

EG with viscoelastic property
to substitute porcine fat
for meatball preparation

# I. Emulsion gel to improve product stability

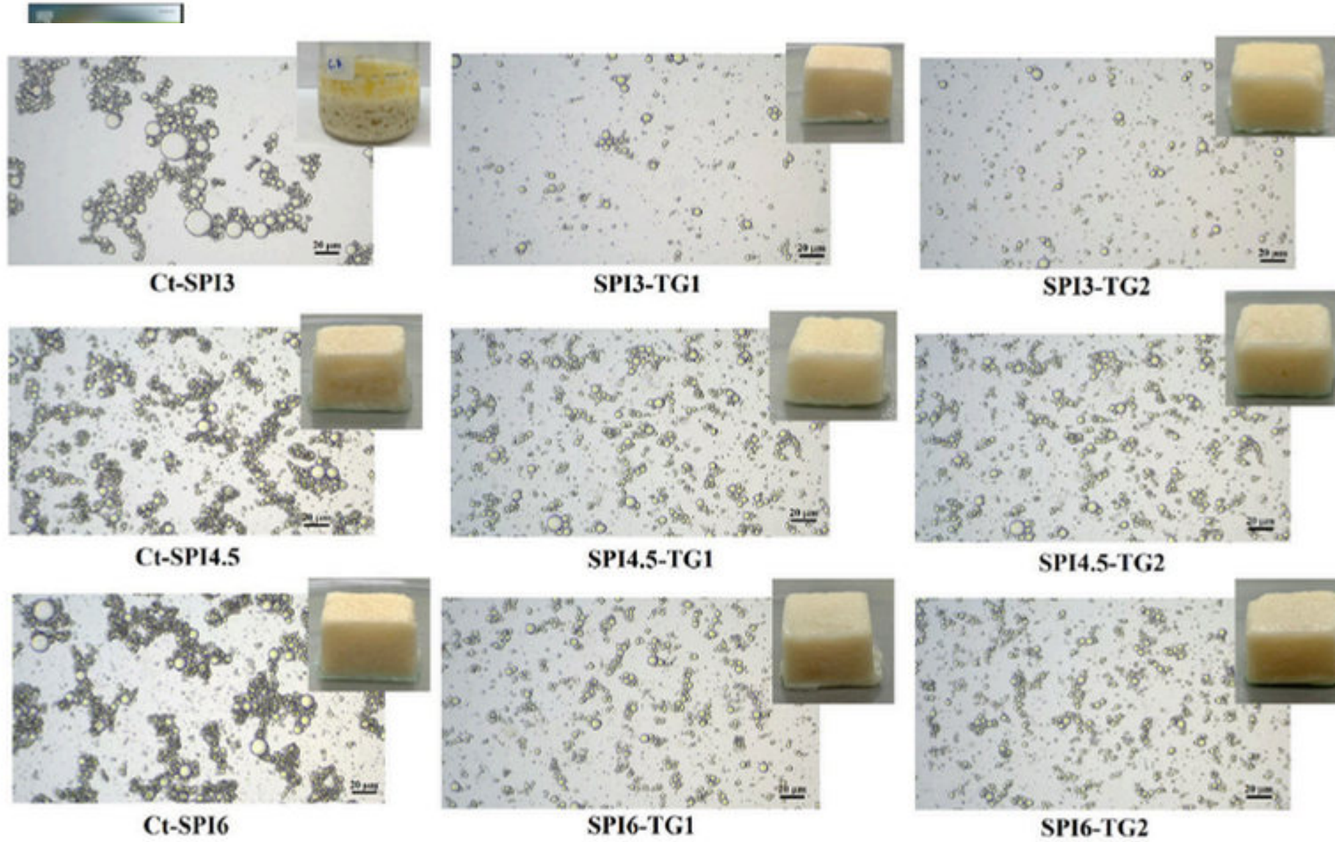



**Fig. 5** Microscopic images of primary emulsion and appearance of the SPI-kCA EG
***From:*** Kerdlapee & Prabsangob (2026)

**Formation of EG with intact structure**

- suitable SPI:kCA ratio
- TGase improved dispersibility of the primary emulsion and gel formability

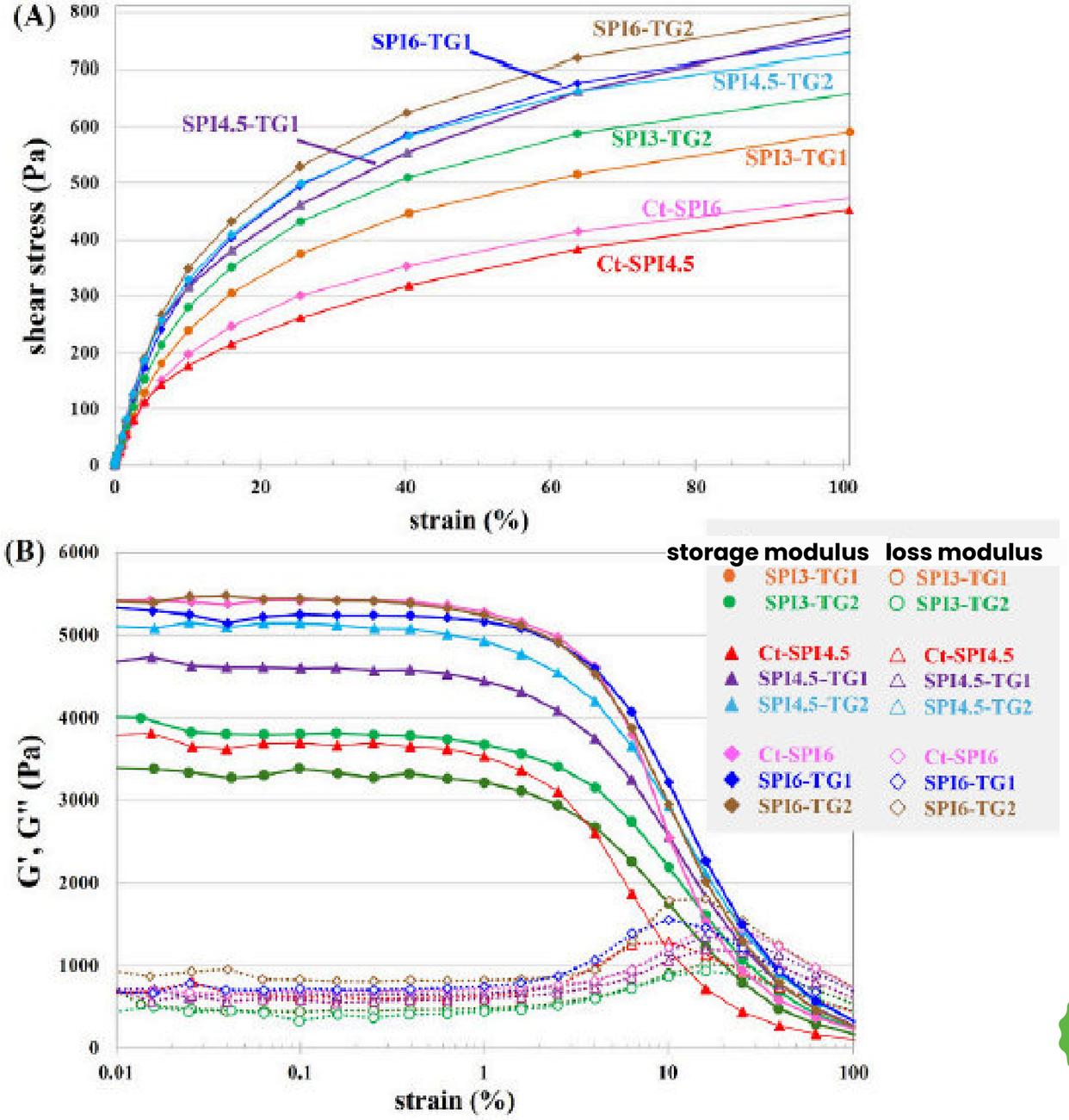



**Fig. 6** Rheological property of the SPI-kCA EG
***From:*** Kerdlapee & Prabsangob (2026)

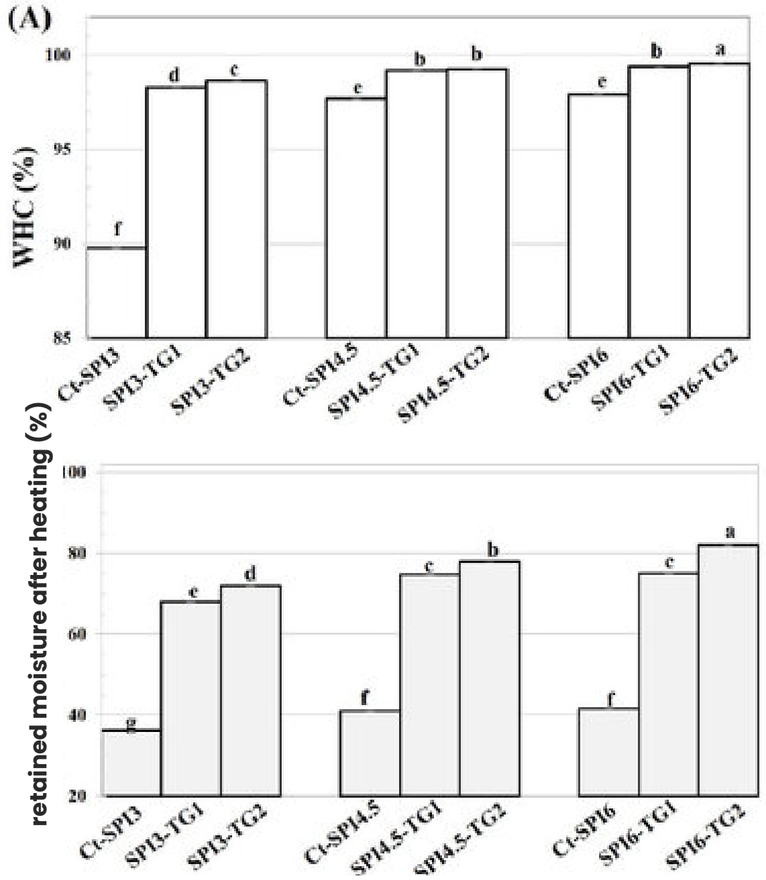
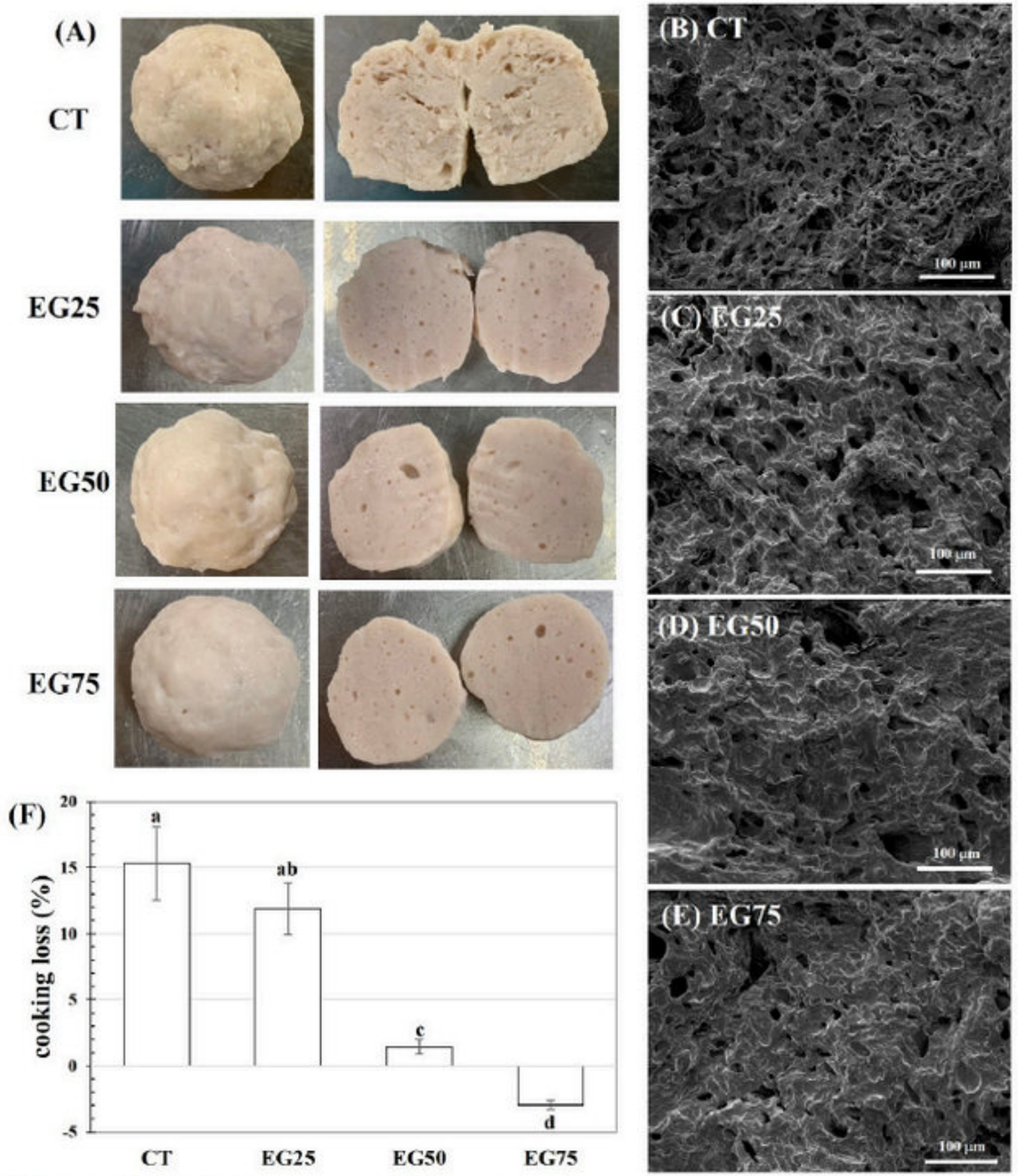



**Fig. 7** WHC and heat induced syneresis of the SPI-kCA EG
***From:*** modified from Kerdlapee & Prabsangob (2026)

**SPI/kCA based EG**

- improved viscosity & viscoelastic property
- enhanced water retainability & heat stability

**TGase importantly promoted gel formability of SPI, thereby strengthen gel network**




In subfigures **(B)–(E)**, bars represent 100 µm

In subfigure **(F)** values (mean ± standard error) with different letters are significantly different ($p \leq 0.05$).

**Substitution of porcine fat using the fabricated SPI/kCA EG**

↓

**strong protein gel matrix as suggested by dense emulsified meat matrix with less pore formation**

↓

**lowered cooking loss**

- **improved batter viscosity**
- **viscoelasticity of the EG**
- water retainability of the gelators

**feasibility of the EG to maintain stability of the SFA reduced meatballs**

**Fig. 8** Appearance, SEM images (300x), and cooking loss of the meatballs incorporated with the TGase treated SPI/kCA EGs
***From:*** modified from Kerdlapee & Prabsangob (2026)

# Emulsion gel to improve storage stabiltiy



Food Chemistry 340 (2021) 128095

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

## Phenolic compounds in emulsion gel-based delivery systems applied as animal fat replacers in frankfurters: Physico-chemical, structural and microbiological approach

Tatiana Pintado*, Irene Muñoz-González, Marina Salvador, Claudia Ruiz-Capillas, Ana M. Herrero*

*Institute of Food Science, Technology and Nutrition (ICTAN-CSIC), José Antonio Novais 10, 28040 Madrid, Spain*

**INGREDIENT**

SPI + Na-alginate
olive oil (oil fraction 0.4)
phenolic rich plant extracts

**cold set gelation**

**KEY FEATURE**

The frankfurters with improved storage stability

**5 % SPI + 40 % olive oil + 4 % alginate**

grape seed extract (G)
grape seed and olive extracts (GO)

EG formation

porcine fat substitution

frankfurters

- N-F: porcine fat, full fat
- R-F: porcine fat, reduced fat **(50 % fat reduction)**
- R-EG: EG, reduced fat
- R-EPG: EG added with grape seed extract, reduced fat
- R-EPGO: EG added with grape seed and olive extracts, reduced fat

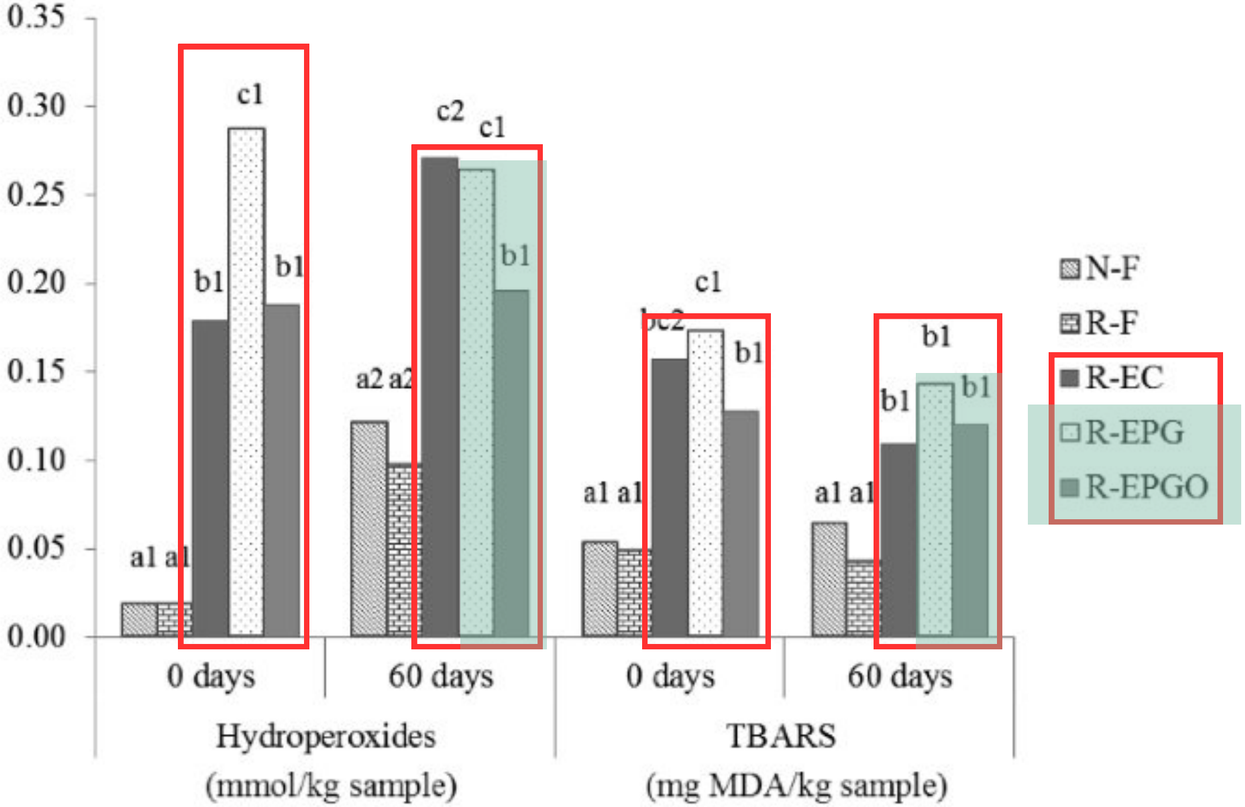



**Fig.9** Storage time dependence on lipid oxidation of the frankfurters
***From:*** Pintado et al. (2021)

**Table 4** Total viable count (TVC) of the frankfurters after 60 day storage at 4C

| frankfurters | TVC (log CFU/g) |
|---|---|
| N-F | 6.24 ± 0.28 |
| R-F | 8.78 ± 0.06 |
| R-EC | 7.39 ± 0.02 |
| R-EPG | 5.11 ± 0.00 |
| R-EPGO | 6.65 ± 0.03 |

**From: Pintado et al. (2021)**

**The frankfurters incorporated with the EGs loaded with phenolic rich plant extracts**

- **lower lipid oxidation**

[the frankfurters added with EG had higher oxidation than the control made from porcine fat]

- **lower microbial growth**

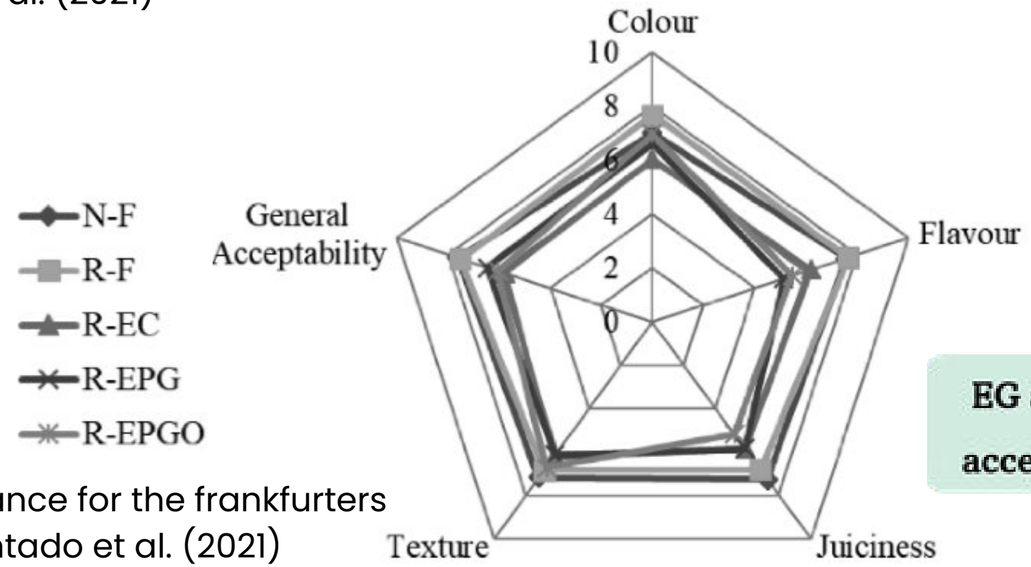



**Fig.10** Sensorial acceptance for the frankfurters
***From:*** modified from Pintado et al. (2021)

**EG adding had no significant effect on sensorial acceptance and textural attributes of the product** → **masking effect**

# Emulsion gel to fabricate fatty acid profile

check for updates

**Citation:** Cîrstea, N.; Nour, V.; Corbu, A.R.; Codină, G.G. Blackcurrant Pomace Extract as a Natural Antioxidant in Vienna Sausages Reformulated by Replacement of Pork Backfat with Emulsion Gels Based on High Oleic Sunflower and Flaxseed Oils. *Gels* **2024**, *10*, 534. https://doi.org/10.3390/gels10080534

*gels*

MDPI

*Article*

## Blackcurrant Pomace Extract as a Natural Antioxidant in Vienna Sausages Reformulated by Replacement of Pork Backfat with Emulsion Gels Based on High Oleic Sunflower and Flaxseed Oils

Nicoleta Cîrstea (Lazăr) [1,2], Violeta Nour [2,*], Alexandru Radu Corbu [2] and Georgiana Gabriela Codină [3]

**INGREDIENT**

SPI + chitosan
sunflower oil+flaxseed oil (0.45 oil fraction)
transgluaminase
Blackcurrant pomace (BCP)

**cold set gelation**

**KEY FEATURE**

The Vienna sausage with **improved fatty acid composition** and **retained stability**

the EG loaded with BCP at varying contents,
i.e., 0%, 0.5%, 1.0% and 2.0%

totally replace porcine fat

the Vienna sausages: VSEG0, VSEG0.5, VSEG1.0, and VSEG2.0

**Table 5** Proximate composition and energy values of the formuated Vienna sausages

| | VSC | VSEG0 | VSEG0.5 | VSEG1.0 | VSEG2.0 |
|---|---|---|---|---|---|
| Moisture (%) | 58.57 ± 1.33 $^{a}$ | 61.46 ± 0.97 $^{b}$ | 59.95 ± 1.11 $^{ab}$ | 59.88 ± 1.48 $^{ab}$ | 60.67 ± 0.83 $^{ab}$ |
| Protein (%) | 12.66 ± 0.45 $^{a}$ | 12.82 ± 0.61 $^{a}$ | 13.21 ± 0.38 $^{a}$ | 13.15 ± 0.49 $^{a}$ | 13.34 ± 0.55 $^{a}$ |
| Fat (%) | 20.32 ± 0.48 $^{c}$ | 17.52 ± 0.52 $^{a}$ | 18.99 ± 0.35 $^{b}$ | 18.62 ± 0.51 $^{b}$ | 18.22 ± 0.67 $^{ab}$ |
| Ash (%) | 2.26 ± 0.16 $^{a}$ | 2.46 ± 0.09 $^{a}$ | 2.39 ± 0.11 $^{a}$ | 2.45 ± 0.14 $^{a}$ | 2.42 ± 0.13 $^{a}$ |
| Energy value (kcal/100 g) | 267.32 ± 2.92 $^{d}$ | 241.76 ± 1.28 $^{a}$ | 255.15 ± 2.69 $^{c}$ | 253.58 ± 3.37 $^{c}$ | 248.42 ± 1.93 $^{bc}$ |

***From:*** modified from Cristea et al. (2024)

**Porcine fat replacement by the EG**

- **lowered fat content and energy value**
- **improved nutritional indices related to cardiovascular health**

- lowered n6/n3 ratio:
 the nutritional guideline suggests as 1:1 - 2:1
- lowered artherogenic (AI) and thrombogenic (TI)

**Table 6** Nutritional indices of the formulated Vienna sausages

| | | | | | |
|---|---|---|---|---|---|
| SFA | 35.49 ± 1.49 $^{b}$ | 23.31 ± 1.05 $^{a}$ | 23.51 ± 0.96 $^{a}$ | 23.11 ± 1.13 $^{a}$ | 23.36 ± 0.93 $^{a}$ |
| MUFA | 46.78 ± 1.38 $^{a}$ | 51.03 ± 1.76 $^{b}$ | 50.89 ± 1.01 $^{b}$ | 51.08 ± 1.34 $^{b}$ | 51.20 ± 1.49 $^{b}$ |
| PUFA | 17.39 ± 0.48 $^{a}$ | 25.31 ± 0.73 $^{b}$ | 25.07 ± 0.97 $^{b}$ | 25.19 ± 0.92 $^{b}$ | 25.19 ± 1.04 $^{b}$ |
| PUFA n-6 | 15.94 ± 0.41 $^{a}$ | 15.47 ± 0.27 $^{a}$ | 15.25 ± 0.58 $^{a}$ | 15.20 ± 0.52 $^{a}$ | 15.16 ± 0.58 $^{a}$ |
| PUFA n-3 | 1.45 ± 0.07 $^{a}$ | 9.84 ± 0.46 $^{b}$ | 9.82 ± 0.39 $^{b}$ | 9.99 ± 0.40 $^{b}$ | 10.03 ± 0.46 $^{b}$ |
| n-6/n-3 | 10.99 | 1.57 | 1.55 | 1.52 | 1.51 |
| AI | 0.45 | 0.23 | 0.24 | 0.23 | 0.23 |
| TI | 0.97 | 0.36 | 0.36 | 0.36 | 0.36 |
| h/H | 2.52 | 4.94 | 4.83 | 4.98 | 4.92 |

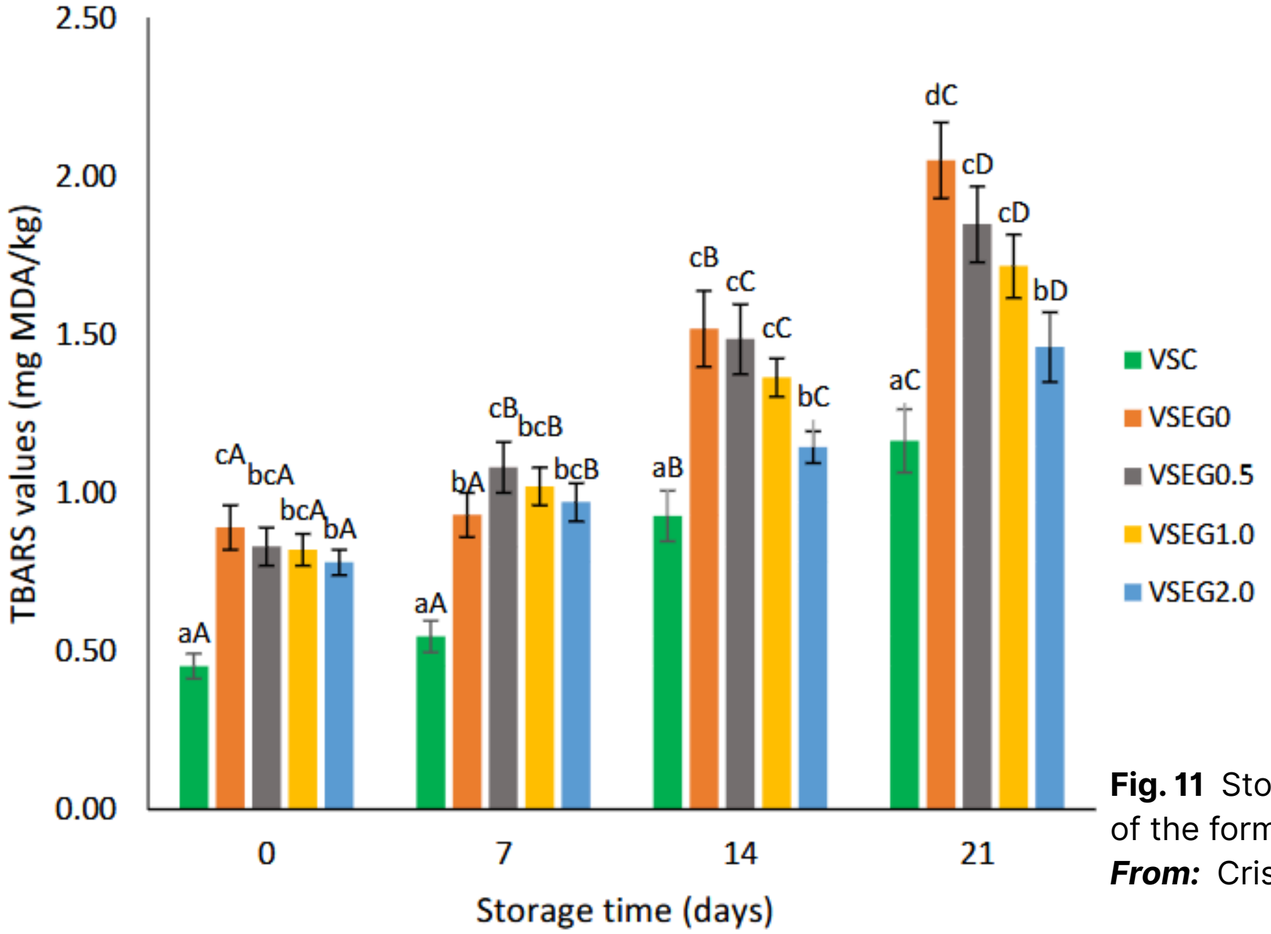
***From:*** modified from Cristea et al. (2024)

**Table 7** Cooking loss and moisture retention of the formuated Vienna sausages

| | VSC | VSEG0 | VSEG0.5 | VSEG1.0 | VSEG2.0 |
|---|---|---|---|---|---|
| Cooking loss (%) | $11.28 \pm 0.44^{b}$ | $8.21 \pm 0.36^{a}$ | $9.02 \pm 0.41^{a}$ | $10.69 \pm 0.54^{b}$ | $13.74 \pm 0.59^{c}$ |
| Moisture retention (%) | $51.96 \pm 0.92^{a}$ | $56.41 \pm 0.67^{d}$ | $54.54 \pm 0.76^{c}$ | $53.47 \pm 1.00^{bc}$ | $52.33 \pm 0.36^{ab}$ |

* Different lowercase letters indicate significant differences between sausage formulations ($p < 0.05$).

***From:*** Cristea et al. (2024)




**Porcine fat replacement by the EG maintained product stability**

- lowered cooking loss
- improved water retainabiltiy
- lowering lipid oxidation during storage

**Fig. 11** Storage time dependence on TBARs contents of the formulated Vienna sausages
***From:*** Cristea et al. (2024)

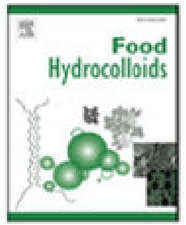
## Emulsion gel to control lipolysis

Food Hydrocolloids 166 (2025) 111335

Contents lists available at ScienceDirect

Food Hydrocolloids

journal homepage: www.elsevier.com/locate/foodhyd




# Exploring the potential of the agar-based emulsion gel as a pork fat substitute in sausage with a focus on the digestive behaviors of lipids and proteins *in vitro*

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[a] Department of Animal Science and Biotechnology, Chungnam National University, 34134, Daejeon, South Korea
[b] Research Group of Food Processing, Korea Food Research Institute, 55365, Wanju, South Korea

**INGREDIENT**

Agar
Alginate
Xanthan gum
Canola oil
Soy lecithin

**cold set gelation**

**KEY FEATURE**

The sausage with a **good physical and chemical stability** along with **controlled lipolysis**

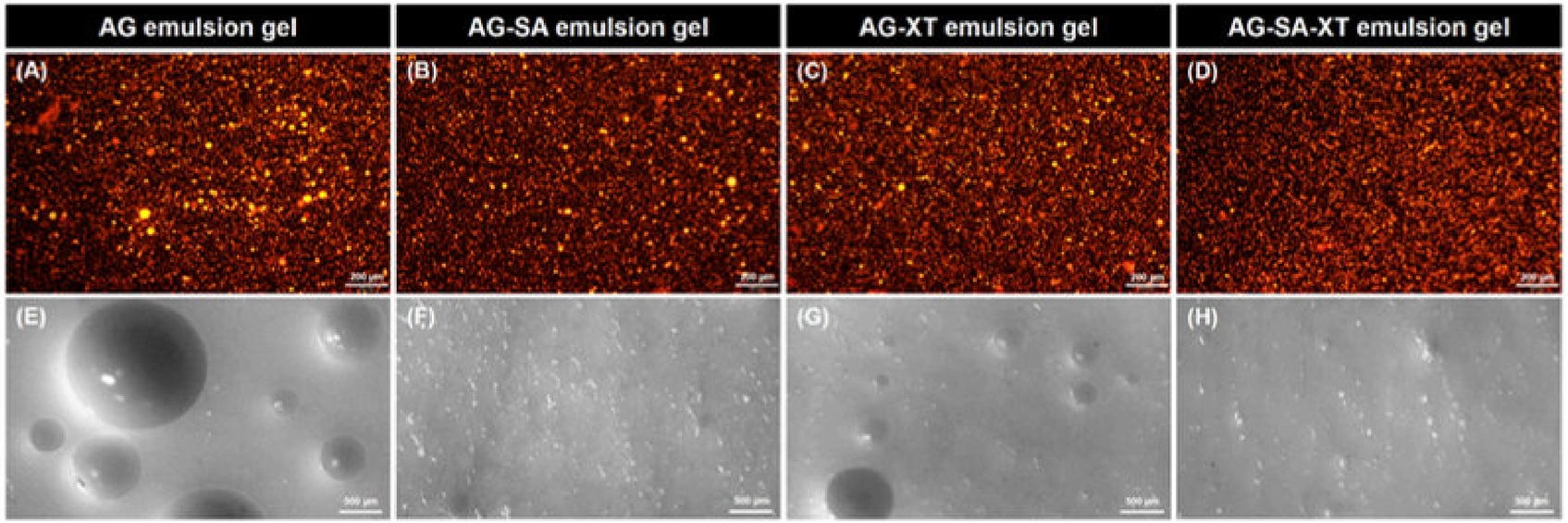



**Fig. 12** Fluorescence microscopic images and surface appearance of the AG, AG-SA, AG-SA-XT EGs
***From:*** Lee et al (2025)

**Table 8** Hardness, fracturability, and springiness of the AG, AS-SA, AG-SA-XT EGs

| | Hardness (g) | Fracturability | Springiness |
|---|---|---|---|
| AG | $4939.85^{A}$ | $0.00^{B}$ | $0.45^{B}$ |
| AG-SA | $2911.87^{B}$ | $0.00^{B}$ | $0.33^{C}$ |
| AG-XT | $5284.50^{A}$ | $3244.77^{A}$ | $0.55^{A}$ |
| AG-SA-XT | $3378.14^{B}$ | $0.00^{B}$ | $0.38^{BC}$ |
| SEM[1] | 112.76 | 3.216 | 0.016 |

[1] Standard error of the least square means

$^{A-C}$ Different letters indicate significant differences between means.
***From:*** Lee et al (2025)

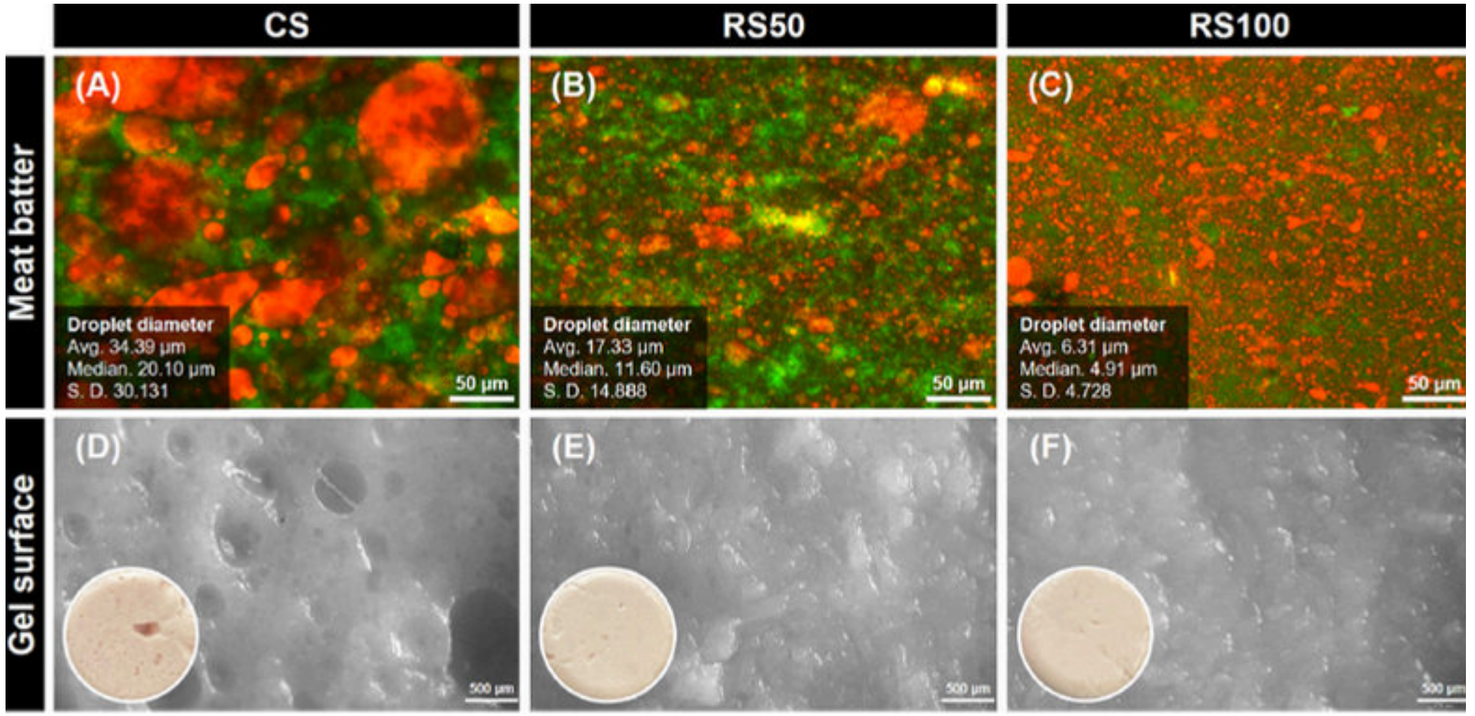
**Agar (AG):** main gelator

**Alginate (SA) and Xanthan gum (XT):** thickening property to enhance gel strength

**SA >>** reduce pore size

**XT >>** impart gel springiness, but increased brittleness of the EGl

- fine dispersed oil droplets
- smooth gel with fewer and smaller sized voids



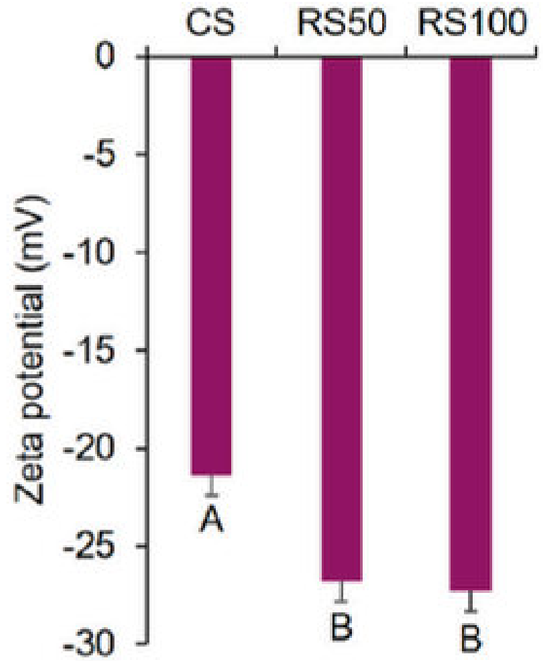




**Fig. 13** Confocal microscopic images, optical microscopic images, and zeta potential of the meat batters of the pork sausage
***From:*** modified from Lee et al (2025)

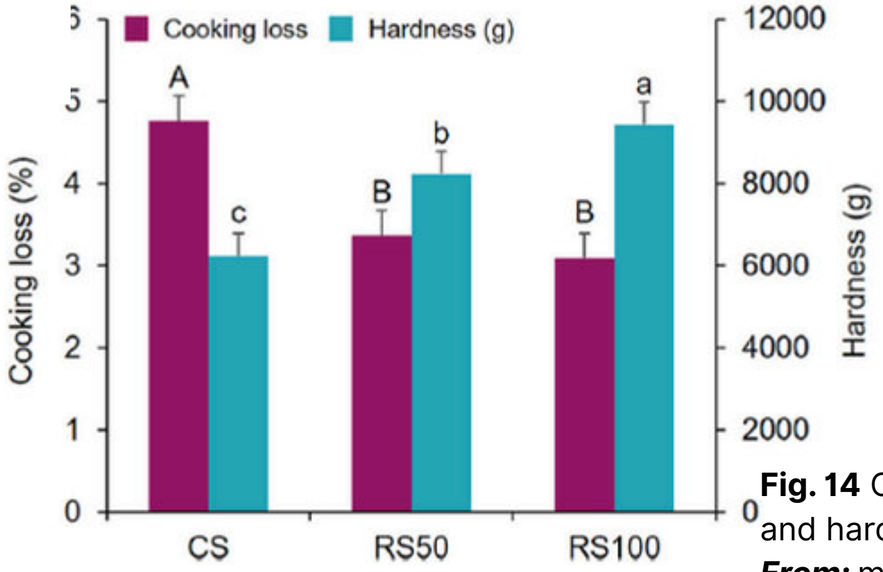



**Fig. 14** Cooking loss,
and hardness of the pork sausages
***From:*** modified from Lee et al. (2025)

**Meat batters added with the AG-SA-XT EG at varying contents**

oil droplet size: **CS > RS50 > RS100**

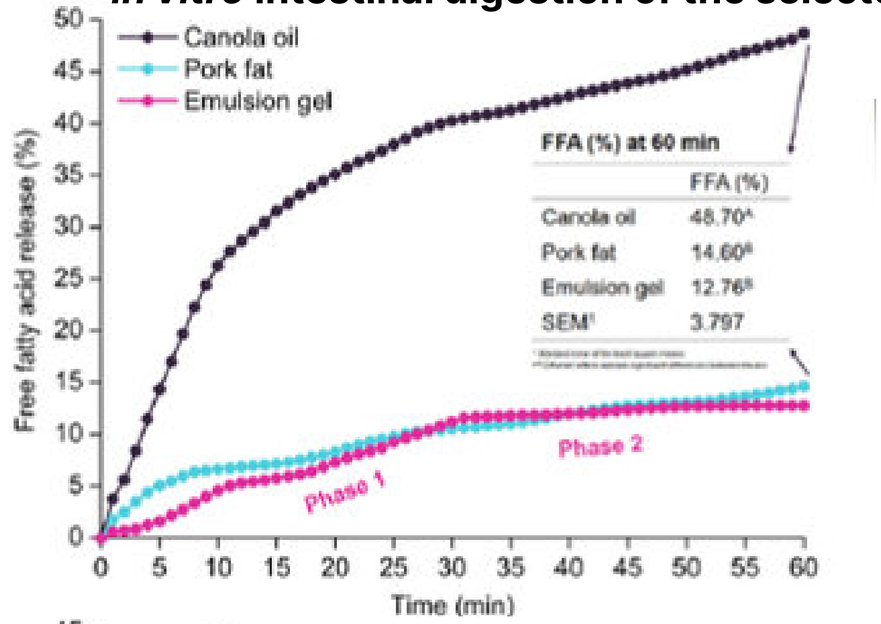
continuity of meat gel network: **RS100 = RS50 > CS**

The polysaccharides used as the structuring agents

- greater electrostatic repulsive force
- water retainability

**sausages structure with greater continuity gel network; improved physical stability; and greater hardness**

***in vitro* intestinal digestion of the selected fat sources**




***in vitro* intestinal digestion of the sausages**

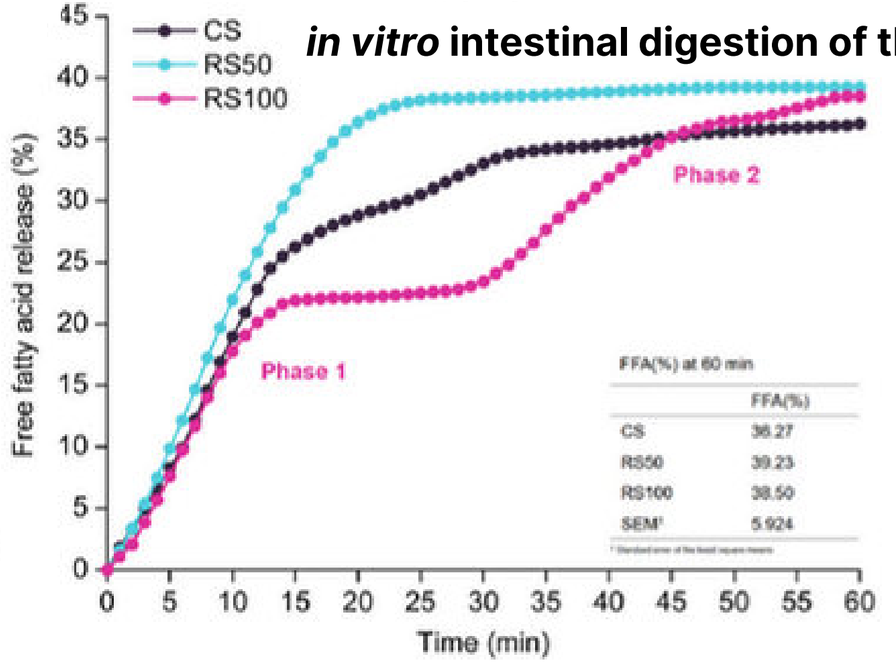



**Fig. 15** FFA release from the fat sources and the sausages after the *in vitro* intestinal digestion
***From:*** modified from Lee et al (2025)

**Lipolysis depends on nature of fat**
increase with polarity of composited fatty acids, particularly for the ones grafted at *sn*-1 and *sn*-3 positions

**EG could lower lipolysis rate of the PUFA rich oil**

**>>** retention of canola oil drops within gel network during the intestinal digestion

**Gel network could physically hindered oil drops from digestive enzymes and bile salts**

Lipolysis rate of the sausages corresponded to the lipolysis trend of used fat source

After 60 min intestinal digestion,
**comparable FFAs were observed for all sausages**

**Physical barrier of the EG interfacial layer** around oil drops led to reduced enzyme accessibility, **thereby lowering lipolysis, despite the higher lipid digestibility of canola oil than pork fat.**

## III. Emulsion gel to strengthen competitiveness

**reformulation** → **redesigning "product value"**



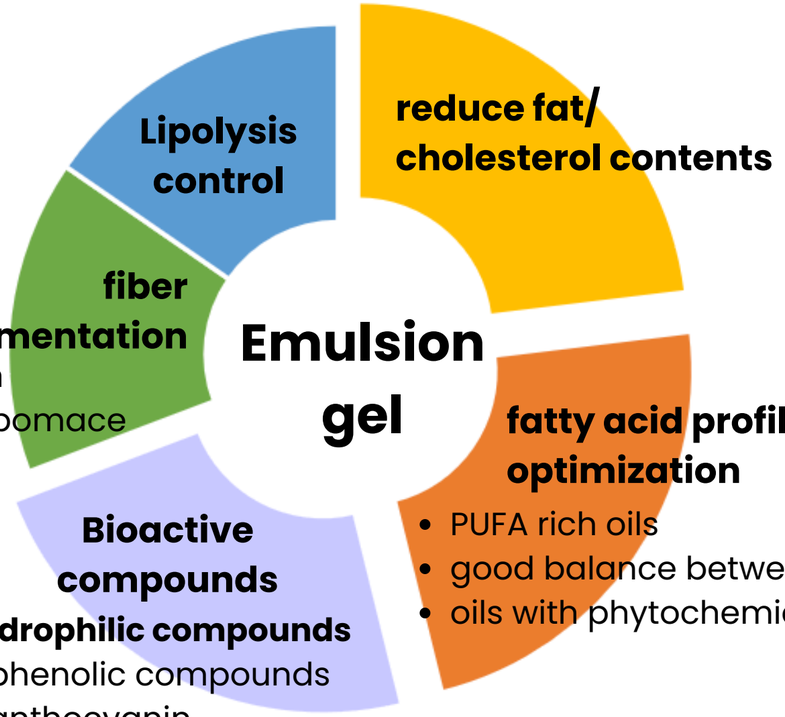

Emulsion gel →

- value creation
- affordable processing
- effective cost

# Emulsion gel: One technology

## multiple claim/positioning

## "value creation"




- inulin
- fruit pomace
- PUFA rich oils
- good balance between n6/n3
- oils with phytochemicals

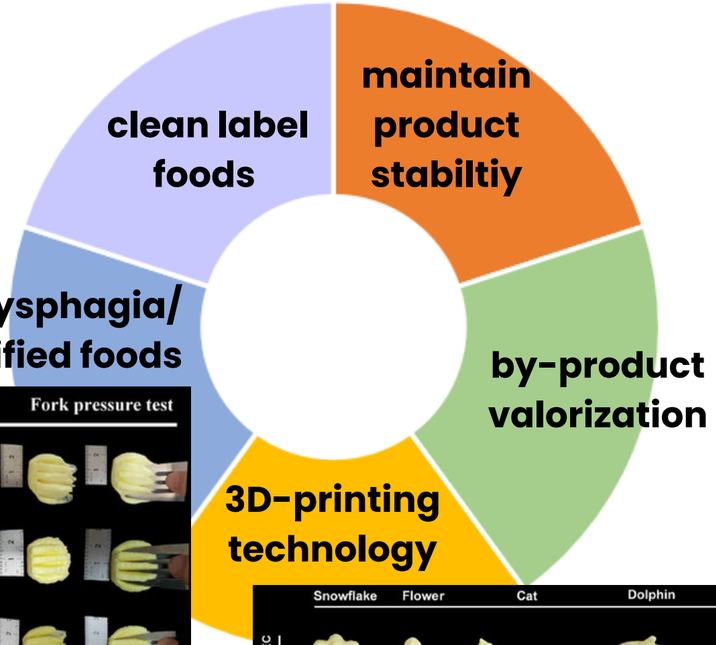
**hydrophilic compounds**

- phenolic compounds
- anthocyanin

**Lipophilic compounds**

- curcumin
- tocols

## "support future food trend"



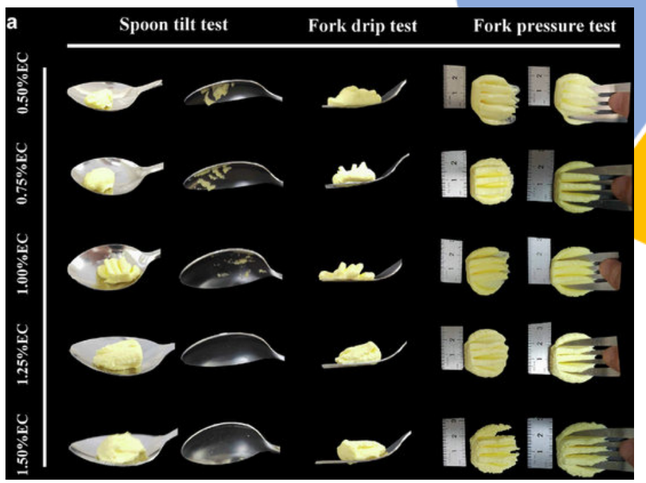




**Fig. 16** The swallowing performance of egg yolk CMC EGs according to the IDDSI.
***Form:*** modified from Hou et al (2025)

**The egg yolk-CMC EGs: classified as a level 5 food**
IDDSI: The international dysphagia dietary standardization initiative to evaluate the swallowing safety
**i.e., the food can be easily chewed and swallowed by tongue force alone without biting**

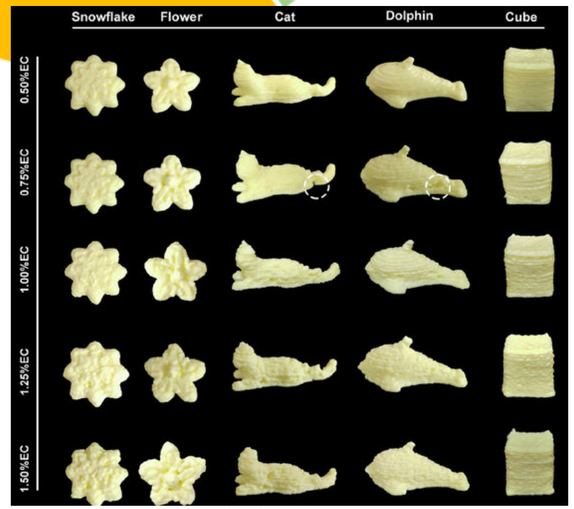



**Fig. 17** The 3D printing performance of egg yolk-CMC EGs
***Form:*** modified from Hou et al (2025)

# Emulsion gel: affordable processing

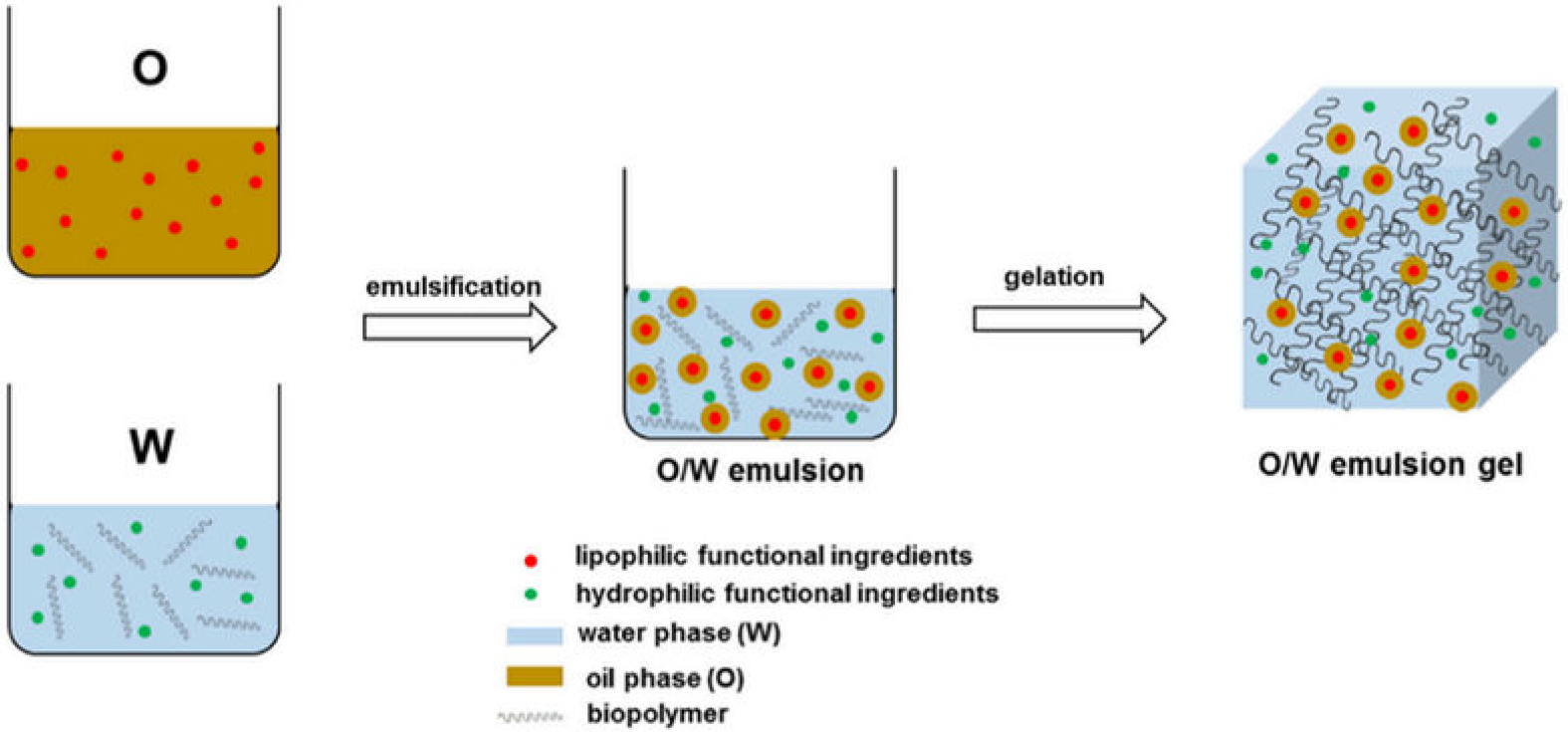



**Fig. 18** Preparation of EG
***From:*** modified from Lu et al (2019)

## STAGE I: Emulsification

- **stable emulsion**
  - emulsifier
  - oil-to-water ratio
  - emulsification technique

## STAGE II: Gelation

**interaction between gelators as well as gelators-oil phase**

**Heat set gelation** (always ≥ 65 °C)
- heating condition
- protein concentration

**Cold set gelation**
- acid induced gelation

e.g., citric acid and glucono-δ-lactone
- salt induced gelation

e.g., $CaCl_2$
- enzyme induced gelation

e.g., transglutaminase

**Homogenization process**
- high speed homogenizer
- colloid mill

**Gelators: proteins and polysaccharides**
- biopolymers usually as Generally Recognized as Safe (GRAS)
- compatible cost

**Table 9** Estimated cost for EG raw materials

| ส่วนประกอบ | ต้นทุน (บาท/100 kg เจล) | ต้นทุน (บาท/kg เจล) |
|---|---|---|
| โปรตีนถั่วเหลือง 4% | 3,200.00 | 32 |
| น้ำมันถั่วเหลือง 50% | 2,989.13 | 29.89 |
| คาราจีแนน 2% | 1,600.00 | 16 |
| TGase 0.08% | 64 | 0.64 |
| **รวมต้นทุนวัตถุดิบ** | **7,853.13** | **78.53** |
| ค่าน้ำ/ไฟและการปั่นผสม | **785.31** | **7.85** |
| **ต้นทุนเจลรวม** | **8,638.44** | **86.38** |

The EG was fabricated based on the study of Kerdlapee and Prabsangob (2026)

## Total product economics

ingredient cost
yield / cooking loss
processing & energy
shelf-life / waste
product value

**Table 10** Estimated cost for the sausages added with the SPI-kCA EG treated with TGase

| ระดับทดแทนไขมันหมู | ไขมันหมู (kg/100 kg) | เจล (kg/100 kg) | ต้นทุนไขมันหมู (บาท) | ต้นทุนเจล (บาท) | ต้นทุนรวม (บาท/100 kg) | ต้นทุน (บาท/kg ไส้กรอก) | ลดต้นทุนเทียบ Control |
|---|---|---|---|---|---|---|---|
| **0% Control** | 35 | 0 | 3,150.00 | 0 | **3,150.00** | **31.5** | – |
| **25%** | 26.25 | 8.75 | 2,362.50 | 755.86 | **3,118.36** | **31.18** | **1.00%** |
| **50%** | 17.5 | 17.5 | 1,575.00 | 1,511.72 | **3,086.72** | **30.87** | **2.01%** |

The sausage formula as per the study of Kerdlapee and Prabsangob (2026)

reformulation → Innovative to create “product value” → compete

**Emulsion gel**

innovative technology
for product value design
with affordable processing

**meat products**

- health-friendly
- functional product
- sustainable/up-cycle
- specialized/personalized foods

# Thank You

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