An RSM study on the twin-screw extrusion of pea protein isolate for meat analogs

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Abstract

Background

High-moisture texturized vegetable protein is an emerging alternative protein source that holds great significance for vegetarians and individuals with sensitivities to animal proteins. Therefore, studying how to enhance extrusion production and processing conditions is crucial to ensure product quality and efficiency. Through the Response Surface Methodology (RSM) method, we can systematically evaluate the impact of different operating conditions on product performance, improving the production process and product quality.

Methods

This study primarily investigated the changes in physical properties of extruded pea protein isolate (PPI) with different levels of feed moisture content and die temperature for high-moisture meat analogs (HMMA) using the RSM. The feed moisture content was set at 55%, 62.5%, and 70%, while the die temperature was set at 130°C, 140°C, and 150°C for the study.

Results

According to experimental results, varying the feed moisture content significantly affected the colors, hardness, chewiness, cohesiveness, and cutting force of HMMA, whereas varying the die temperature did not. This could be attributed to the direct impact of changes in feed moisture content, which affected the texture and flavor of the product. Conversely, the effect of die temperature did not have any influence, perhaps because it remained relatively stable within the range set. However, with an increase in die temperature, hardness, and chewiness tend to decrease, while the L value, cooking loss rate, and pressure value of system variables tend to increase.

Conclusion

Overall, this study's findings offered valuable insights into the production of HMMA, aiding in further refining extrusion processing conditions and enhancing product quality and efficiency.

Keywords: twin-screw extrusion, pea protein isolate, meat analogs

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Introduction

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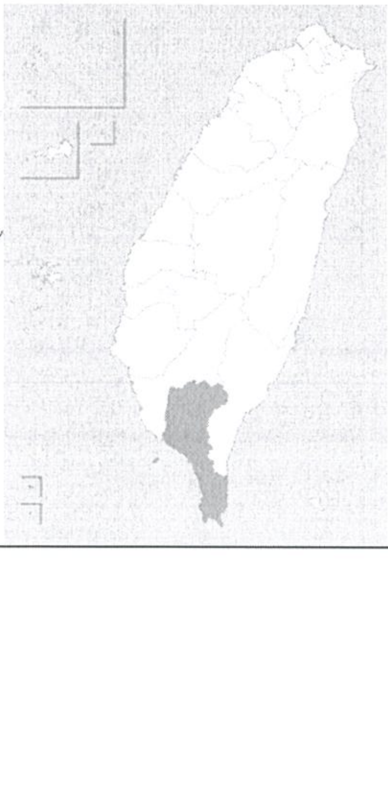

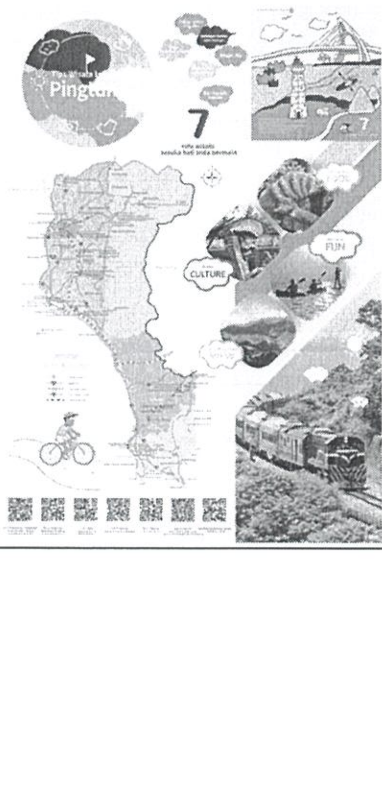

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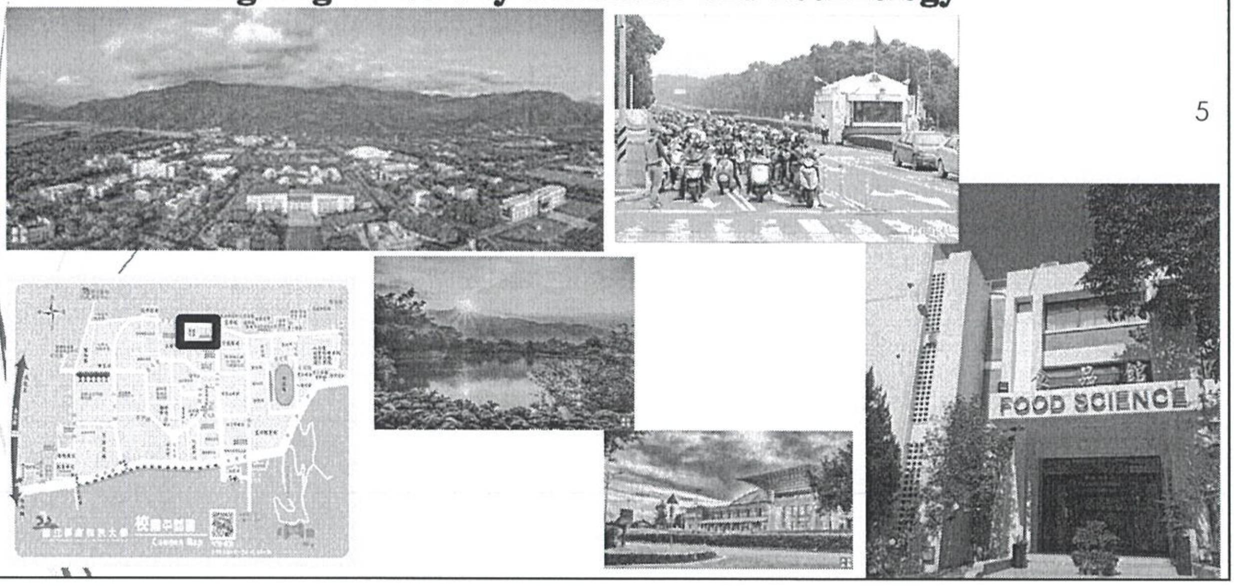

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Introduction

- In September 2015, the United Nations (UN) General Assembly adopted the 2030 Agenda for Sustainable Development. 17 Sustainable Development Goals (SDGs) present a novel approach and incentive to prioritize and integrate a number of pressing issues, including food security, food sustainability and climate change etc. (Aiking and de Boer, 2020)
- High-moisture texturized vegetable protein is an emerging alternative protein source that holds great significance for vegetarians and individuals with sensitivities to animal proteins.
- Therefore, studying how to enhance extrusion production and processing conditions is crucial to ensure product quality and efficiency.

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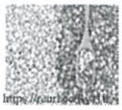
Introduction



- Pulse proteins are regarded as a promising alternative.

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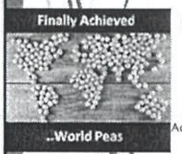
The consumption of plant-derived protein sources, including pulses, is associated with a lower incidence of chronic illness such as cardiovascular disease and diabetes.

(Martineau-Côté *et al*., 2023)

- Pea protein can be considered a high-quality protein owing to its balanced amino acid ratio, and all essential amino acids, except for methionine, that can fulfil FAO/WHO recommendations.
- Commercially, pea protein ingredients are available as flours, concentrates or isolates.



(Boukid *et al*., 2021)

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Introduction

- In recent years, the texturization of pulse proteins into matrices for use as meat analogues has attracted significant attention from industrial as well as academic researchers. Twin-screw extrusion is the main technique employed in such investigations.
- From published studies, it emerges that the main variables impacting the texture of extruded pulse ingredients are the water content, the temperature and shear rate during processing.

(Muhialdin and Ubbink, 2023)

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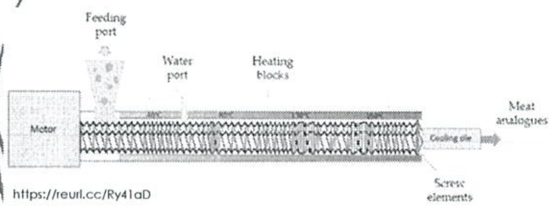
- The high-moisture extrusion process (HMEP) is a high temperature and shear-intensive process where protein unfolding, aggregation, and cross-linking, combined with a dramatic temperature drop at the cooling die, leads to formation of meat-like fibrous structures.

(Pöri *et al*., 2023)



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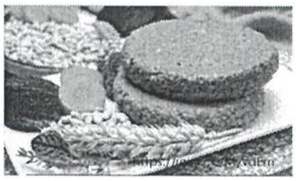

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Objective

- Through the Response Surface Methodology (RSM) method, we can systematically evaluate the impact of different operating conditions on product performance, improving the production process and product quality.

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Materials and Methods

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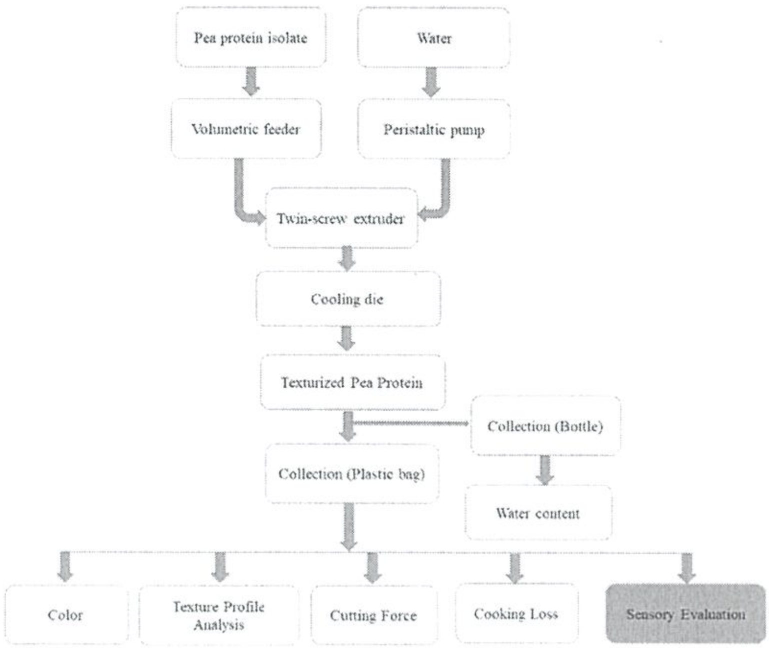

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3 Results and Discussion

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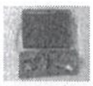
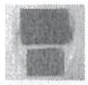
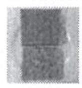
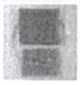
Run	Feed moisture content	Die temperature	Extrudate	Run	Feed moisture content	Die temperature	Extrudate
1	55%	150℃		8	70%	150℃	
2	55%	140℃		9	62.5%	140℃	
3	70%	130℃		10	62.5%	140℃	
4	62.5%	150℃		11	62.5%	140℃	
5	62.5%	130℃		12	62.5%	140℃	
6	62.5%	140℃		13	70%	140℃	
7	55%	130℃					

Table 2. Color analysis of textured pea protein isolate at different feed moisture contents and die temperatures

Feed moisture content	Die temperature	L*	a*	b*
55%	130℃	46.04 ± 0.74^{g}	7.79 ± 0.11^{c}	14.86 ± 0.45^{f}
62.5%	130℃	51.52 ± 0.76^{e}	8.19 ± 0.22^{b}	17.79 ± 0.30^{b}
70%	130℃	57.64 ± 1.17^{b}	7.33 ± 0.33^{e}	16.80 ± 0.55^{d}
55%	140℃	46.29 ± 1.07^{g}	7.70 ± 0.16^{cd}	14.93 ± 0.44^{f}
62.5%	140℃	52.83 ± 0.58^{cd}	7.81 ± 0.23^{c}	17.34 ± 0.40^{c}
62.5%	140℃	52.98 ± 0.66^{cd}	7.51 ± 0.16^{de}	16.75 ± 0.33^{d}
62.5%	140℃	52.69 ± 1.32^{d}	7.85 ± 0.37^{c}	17.27 ± 0.73^{c}
62.5%	140℃	53.16 ± 0.67^{cd}	8.64 ± 0.29^{a}	18.52 ± 0.37^{a}
62.5%	140℃	53.61 ± 0.68^{c}	7.81 ± 0.25^{c}	17.79 ± 0.40^{b}
70%	140℃	59.08 ± 0.97^{a}	7.01 ± 0.23^{f}	16.51 ± 0.33^{de}
55%	150℃	47.14 ± 0.62^{f}	8.27 ± 0.18^{b}	16.26 ± 0.26^{e}
62.5%	150℃	53.33 ± 0.78^{cd}	7.87 ± 0.20^{c}	17.82 ± 0.19^{b}
70%	150℃	59.12 ± 1.14^{a}	6.87 ± 0.20^{f}	16.44 ± 0.39^{de}

a-g Means with different letters in the same column differ significantly ($p<0.05$) by Duncan's multiple range test, n=10.

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Table 3. Hardness (kg_f) of textured pea protein isolate at different feed moisture contents and die temperatures

Feed moisture content	Die temperature	Hardness (kg_f)
55%	130℃	6.67 ± 0.66^{a}
62.5%	130℃	3.83 ± 0.29^{d}
70%	130℃	1.26 ± 0.23^{g}
55%	140℃	6.62 ± 0.46^{a}
62.5%	140℃	3.98 ± 0.35^{cd}
62.5%	140℃	2.87 ± 0.20^{e}
62.5%	140℃	3.00 ± 0.14^{e}
62.5%	140℃	2.36 ± 0.99^{g}
62.5%	140℃	4.43 ± 0.73^{bc}
70%	140℃	0.90 ± 0.10^{g}
55%	150℃	4.67 ± 0.66^{b}
62.5%	150℃	3.03 ± 0.27^{e}
70%	150℃	0.99 ± 0.16^{g}

a-g Means with different letters in the same column differ significantly ($p<0.05$) by Duncan's multiple range test, n=6.

Table 4. Cutting force of textured pea protein isolate at different feed moisture contents and die temperatures

Feed moisture content	Die temperature	Cutting force longitudinal	Cutting force transversel	Degree of texturization
55%	130℃	1.16±0.002[b]	1.58±0.06[a]	1.36
62.5%	130℃	0.59±0.03[g]	0.64±0.01[e]	1.09
70%	130℃	0.34±0.02[j]	0.48±0.01[f]	1.41
55%	140℃	1.31±0.06[a]	1.46±0.05[b]	1.12
62.5%	140℃	0.65±0.02[f]	0.70±0.03[d]	1.08
62.5%	140℃	0.34±0.02[j]	0.25±0.01[i]	0.74
62.5%	140℃	0.50±0.02[h]	0.48±0.02[f]	0.96
62.5%	140℃	0.45±0.02[h]	0.44±0.01[g]	0.98
62.5%	140℃	0.79±0.04[d]	0.63±0.01[e]	0.8
70%	140℃	0.24±0.01[k]	0.30±0.01[h]	1.25
55%	150℃	1.12±0.05[c]	1.36±0.05[c]	1.21
62.5%	150℃	0.75±0.04[e]	0.63±0.02[e]	0.84
70%	150℃	0.51±0.001[h]	0.64±0.01[e]	1.26

a-k Means with different letters in the same column differ significantly ($p<0.05$) by Duncan's multiple range test, n=8.

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Table 5. Cooking loss of textured pea protein isolate at different feed moisture contents and die temperatures

Feed moisture content	Die temperature	Cooking loss
55%	130℃	5.22±0.04[def]
62.5%	130℃	4.81±0.24[ef]
70%	130℃	5.20±0.73[def]
55%	140℃	5.11±0.12[def]
62.5%	140℃	5.59±0.49[cd]
62.5%	140℃	5.00±0.35[def]
62.5%	140℃	4.57±0.33[f]
62.5%	140℃	5.32±0.58[cdef]
62.5%	140℃	5.97±0.22[c]
70%	140℃	5.56±0.26[cde]
55%	150℃	5.32±0.16[cdef]
62.5%	150℃	6.66±0.44[b]
70%	150℃	9.33±0.51[a]

a-f Means with different letters in the same column differ significantly ($p<0.05$) by Duncan's multiple range test, n=3.

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Conclusions and future work

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Conclusions and future work

Added ingredients
Rice protein & corn starch

Change extrusion die
Cooling die (high moisture extrusion)
Expansion die (low moisture extrusion)

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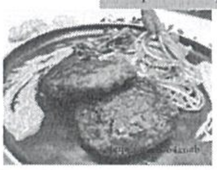
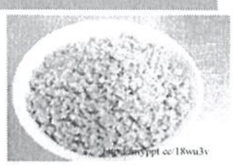
- High-moisture extrusion (vegetarian hamburger steak, vegetarian sausage)
- Low-moisture extrusion (vegetarian minced meat, pea protein puffed snacks)





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Conclusions and future work

Based on the research results, it is known that as the die temperature increases and the feed moisture content decreases, the color, hardness, and cutting force all increase significantly. Therefore, a die temperature of 140°C and a feed moisture content of 62.5% yield better results.

Overall, this study's findings offered valuable insights into the production of HMMA, aiding in further refining extrusion processing conditions and enhancing product quality and efficiency.

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