Study on the twin-screw extrusion of soy protein isolate using response surface methodology

Shang-Wen Chung, Jenshinn Lin

Department of Food Science, National Pingtung University of Science and Technology, Pingtung 91201, Taiwan-ROC

Background

Twin-screw extrusion plays a vital role in soy protein production within food processing due to its inherent advantages. This study explores the impact of feed moisture content (FMC) and die temperature (DT) on the physical attributes of high-moisture meat analogs (HMMA), delving into their influence on product quality and optimizing the production process.

Methods

Utilizing response surface methodology (RSM), we assess how FMC and DT affect the appearance, color, hardness, springiness, cohesiveness, chewiness, cutting force, and cooking loss of HMMA. Altering processing variables allows us to gauge their effects on system variables like pressure, motor torque, and specific mechanical energy (SME), establishing correlations with the final product quality.

Results

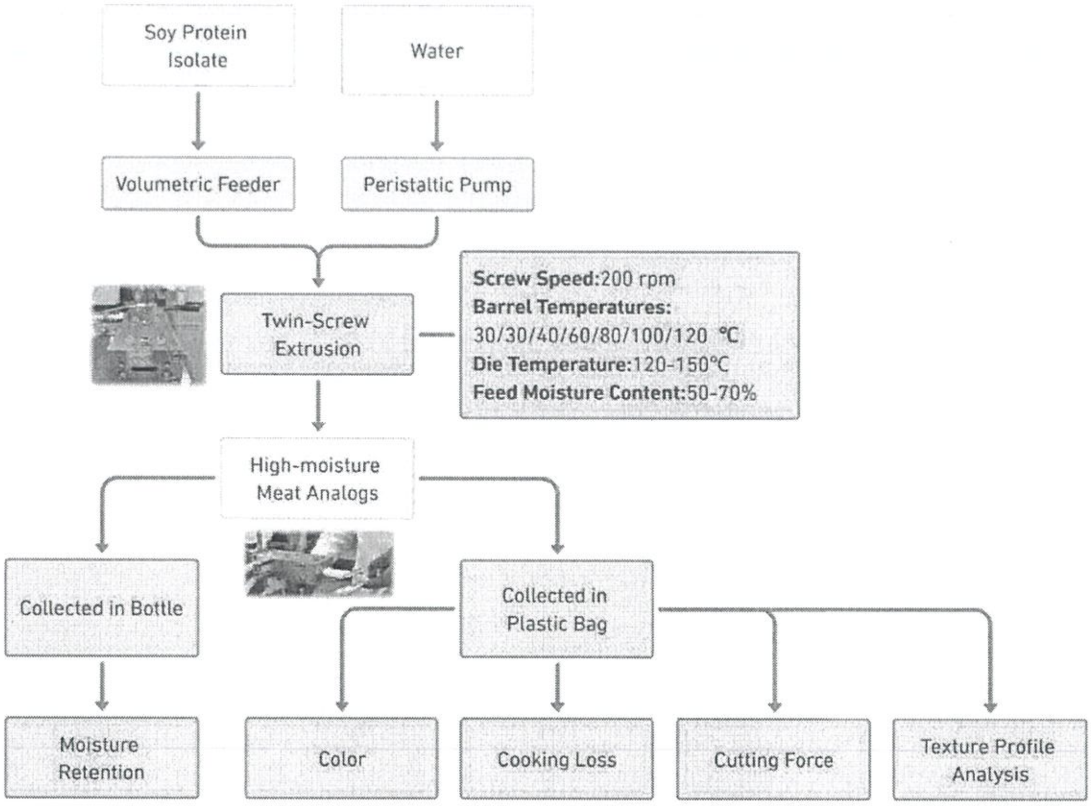
Results reveal that at 70% FMC, HMMA display a lighter color but excessively soft texture, resembling dough without a discernible structure. At 50%, deeper color and a distinct textured structure are observed; however, lower moisture content hinders hand tearing, and softening through soaking aids in observation. Moisture retention results indicate minimal differences in extrudate moisture content at various FMC levels, showcasing high control precision. The RSM coefficient table highlights FMC's significant impact on color, hardness, cohesiveness, chewiness, cutting force, cooking loss, pressure, motor torque, and SME of extrudates, while DT notably affects a*, cohesiveness, and pressure, offering potential control over product quality and processing efficiency.

Conclusion

This study emphasizes the pivotal role of FMC and DT in optimizing the twin-screw extrusion process for soy protein production. Fine-tuning these parameters enables producers to enhance processing efficiency and ensure the production of high-quality products.

Keywords

Twin-screw, Extrusion, High-moisture meat analogs


Soy Protein Isolate
Water
Volumetric Feeder
Peristaltic Pump
Twin-Screw Extrusion
Screw Speed:200 rpm
Barrel Temperatures:
30/30/40/60/80/100/120 ℃
Die Temperature:120-150℃
Feed Moisture Content:50-70%
High-moisture Meat Analogs
Collected in Bottle
Collected in Plastic Bag
Moisture Retention
Color
Cooking Loss
Cutting Force
Texture Profile Analysis

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Presented by: Shang-Wen Chung
Advisor: Prof. Jenshinn Lin

國立屏東科技大學
National Pingtung University of Science and Technology

Department of Food Science
National Pingtung University of Science and Technology
Pingtung 91201, Taiwan-ROC

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Self-information

- Shang-Wen Chung
- 4th year of PhD. program

Past → **Now**

Master's Research Focus

- Extraction and characterization of adzuki bean protein.
- Potential applications in food and nutrition industries.

PhD Research Focus

- Twin-screw extrusion of plant proteins.
- Innovations and advancements in processing techniques.

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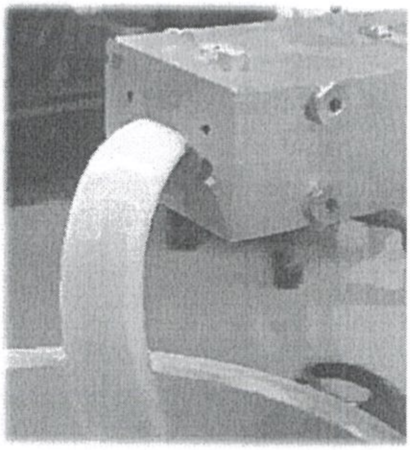
OUTLINE

1. *Object*
2. *Materials and Methods*
3. *Results and Discussion*
4. *Conclusion*



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Object

Extrusion Variables

Process Variables → System Variables → Target Variables

Process Variables	System Variables	Target Variables
Geometric Factors	Dough Rheology	Texture
Screw configuration	Pressure	Crosslink
Die type and dimension	Torque	Gelatinization
Operational Parameters	Specific Mechanical Energy	Polymerization
Dry feed (blends)	Moisture	Conformational changes
Added water	Product temperature	Degradation
Screw speed	Degradation	
Barrel temperature		
Other fluids		

Arora & Yoon *et al.*, 2020; Kristiawan & Della Valle *et al.*, 2022

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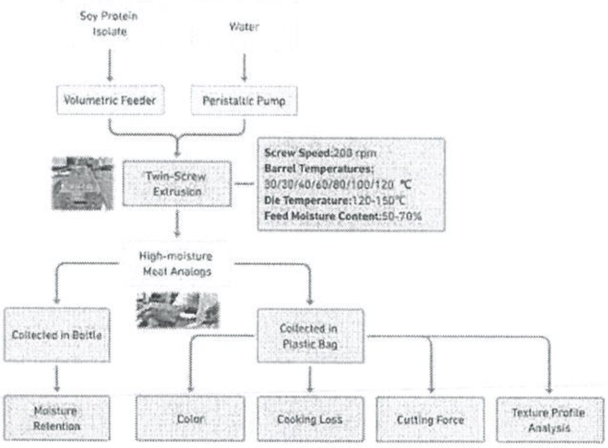
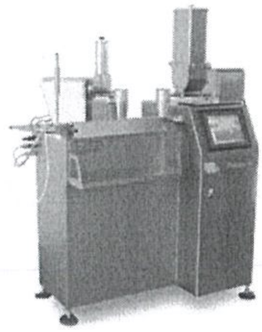
Materials and Methods





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Data recording during extrusion

Real Time h:m:s	Elapsed Time m:s	Screw Speed rpm	Flour Feed Rate %	Water Feed Rate %	Zone 8 Temp °C	Die Temp °C	Melt Temp °C	Torque %	Pressure bar	Power kw
15:10:46	00:00:00	51	0	9.1	140	150	145	1	12.0	0.00
15:10:51	00:00:05	51	0	9.1	140	150	145	1	12.0	0.00
15:10:56	00:00:10	51	0	9.1	140	150	145	1	12.0	0.00
15:11:01	00:00:15	51	2	9.0	140	150	145	1	12.0	0.00
15:11:06	00:00:20	51	2	9.1	140	150	145	1	12.0	0.00
15:11:11	00:00:25	51	2	9.1	140	150	145	1	12.0	0.00
15:11:16	00:00:30	51	2	9.0	140	150	145	1	12.0	0.00
15:11:21	00:00:35	51	2	9.0	140	150	145	1	12.0	0.00
15:11:26	00:00:40	51	2	9.0	140	150	145	1	12.0	0.00
15:11:31	00:00:45	51	2	9.1	136	150	145	1	12.0	0.00
15:11:36	00:00:50	51	3	9.1	131	150	145	1	11.9	0.00
15:11:41	00:00:55	51	4	9.0	126	150	145	1	9.9	0.00
15:11:46	00:01:00	51	4	9.1	125	149	144	2	9.0	0.00
15:11:51	00:01:05	101	4	8.9	124	144	143	2	9.0	0.00
15:11:56	00:01:10	101	4	9.1	124	143	141	2	9.0	0.00
15:12:01	00:01:15	101	4	8.9	124	142	140	3	9.2	0.01
15:12:06	00:01:20	101	4	8.9	124	141	138	4	9.4	0.01
15:12:11	00:01:25	101	4	9.1	125	141	137	5	9.6	0.01

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Results and Discussion

System Variables in twin-screw extrusion

No.	FMC %	DT °C	Pressure (bar)	Torque (%)	Power (kW)	SME (kWh/kg)
1	60	135	21.70	9.24	0.0624	0.00037
2	60	150	24.16	9.51	0.0651	0.00040
3	70	135	14.36	5.03	0.0303	0.00007
4	60	135	21.85	9.66	0.0666	0.00042
5	50	120	28.84	17.21	0.1221	0.00167
6	50	150	34.31	18.34	0.1334	0.00194
7	70	150	16.32	5.56	0.0358	0.00010
8	70	120	14.33	5.35	0.0334	0.00009
9	60	120	20.31	9.67	0.0669	0.00041
10	60	135	21.39	11.85	0.0874	0.00066
11	60	135	19.38	11.05	0.0805	0.00057
12	60	135	17.95	9.79	0.0678	0.00042
13	50	135	29.81	18.42	0.1329	0.00196

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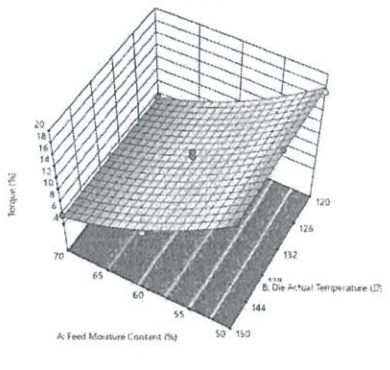
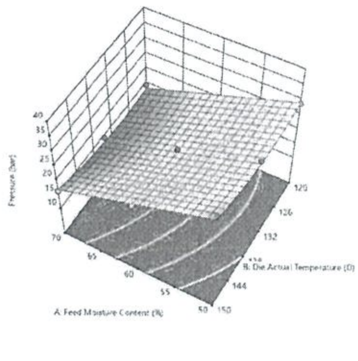
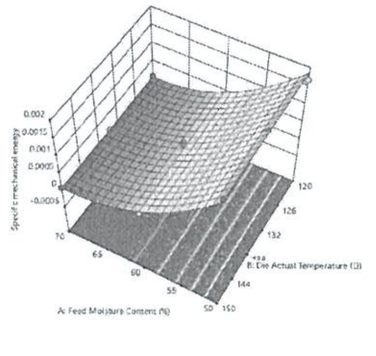
Torque



Pressure



Specific Mechanical Energy



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	Intercept	A (FMC)	B (Die Temperature)	AB	A²	B²
Water content	61.22235469	10.01510819				
p-values		< 0.0001				
L*	53.89171795	7.379166667				
p-values		< 0.0001				
a*	1.278846154	-0.155833333	0.158888889			
p-values		0.0092	0.0083			
b*	13.43862069	1.635833333	-0.005833333		-0.61938908	-0.581008747
p-values		< 0.0001	0.9500		0.0016	0.0024
Hardness	8.917780077	-8.959303333	1.203106667			
p-values		0.0002	0.4126			
Springiness	3.053865714	0.019653333			-0.242889048	
p-values		0.2558			0.8371	
Chewiness	171.0412815	-148.2365235				
p-values		0.0002				
Cohesion force resilience	0.918588966	0.012946667	0.003716667	-0.00084	-0.005981379	0.005308621
p-values		< 0.0001	0.0467	0.5422	0.0016	0.0821
Cutting force (longitudinal)	4.237827143	-4.42727			1.337972857	
p-values		< 0.0001			0.0004	
Cutting force (transversal)	4.719937143	-5.06890	0.320813333	-0.811175	1.92448819	
p-values		< 0.0001	0.0781	0.0031	< 0.0001	
Degree of texturization	1.204877783	0.224618154	-0.106673089	-0.267210674		
p-values		0.2898	0.3631	0.0504		
Cooking loss	9.625671455	2.8481206	-0.846484667		2.420957045	
p-values		0.0001	0.1829		0.0080	
Torque	20.1097711	-6.358291542			1.542951093	
p-values		< 0.0001			0.0065	
Pressure	20.92013826	-7.951726842	1.885838735			2.125972665
p-values		< 0.0001	0.0149			0.0320
Specific mechanical energy	0.000465416	-0.00088547			0.000509872	
p-values		< 0.0001			< 0.0001	

Coefficients Table

Impact of **Feed Moisture Content (FMC)** and **Die Temperature** on System and Target Variables in twin-screw extrusion

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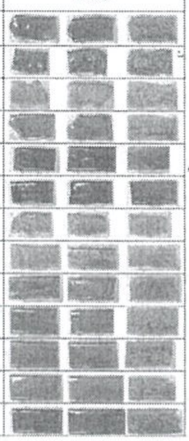
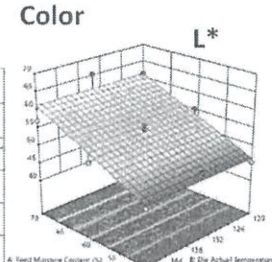
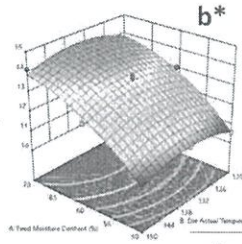
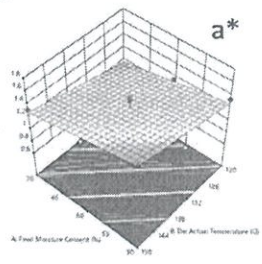
Color

Run	FMC %	Die Temp ℃	Picture
1	60	135	
2	60	150	
3	70	135	
4	60	135	
5	50	120	
6	50	150	
7	70	150	
8	70	120	
9	60	120	
10	60	135	
11	60	135	
12	60	135	
13	50	135	









No.	FMC %	DT ℃	L*	a*	b*
1	60	135	53.69±4.58	1.40±0.32	13.53±0.68
2	60	150	51.24±4.90	1.38±0.40	12.50±0.46
3	70	135	65.40±0.42	1.04±0.21	14.32±0.46
4	60	135	53.82±5.63	1.39±0.24	13.40±2.00
5	50	120	45.26±4.19	1.34±0.19	10.59±1.88
6	50	150	45.71±0.97	1.61±0.20	10.63±0.63
7	70	150	57.10±4.11	1.32±0.28	14.17±0.62
8	70	120	61.28±3.85	0.87±0.35	13.70±0.77
9	60	120	55.47±1.85	1.15±0.06	13.05±1.05
10	60	135	52.30±1.40	1.45±0.07	13.33±1.10
11	60	135	54.79±1.95	1.28±0.08	13.37±0.69
12	60	135	56.04±2.14	1.21±0.12	13.69±0.67
13	50	135	48.54±0.90	1.20±0.16	11.15±0.52

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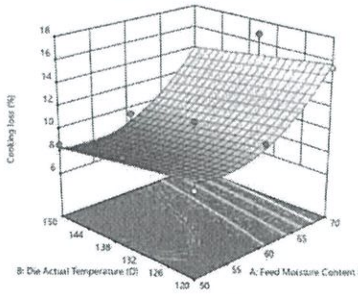
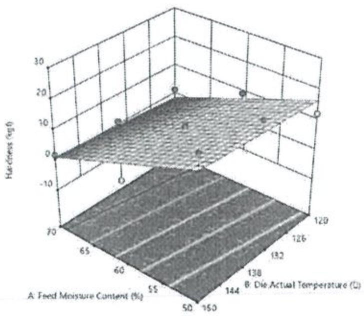
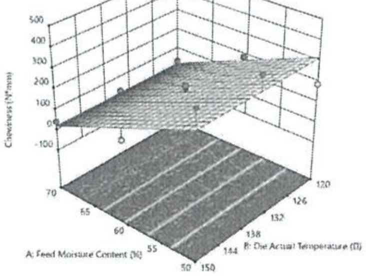
Cooking Loss



Hardness



Chewiness



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Conclusion

- Increasing FMC changes pressure, torque, power, and SME.
- FMC significantly affect the physicochemical properties of twin-screw extruded soy protein isolate.
- Higher FMC increases cooking loss rates; higher DT changes product color(a*).
- Insights are crucial for optimizing production conditions to achieve desired quality and efficiency.

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