Study on the effects and mechanisms of preheating on the freeze-thaw stability of non-fermented frozen dough

预熟制对非发酵冷冻面团冻融品质影响及机理研究

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Introduction

Save equipment labor time costs Promote standardization and industrialization

The demand for frozen non-fermented dough products in the Chinese market is increasing.

Existing problems

Quality deterioration is likely to occur during storage and transportation.

Improvement method

Raw material optimization: wheat varieties, composite flour

Utilization of additives

Optimize dough process: vacuum kneading, preheating

Optimize the freezing process

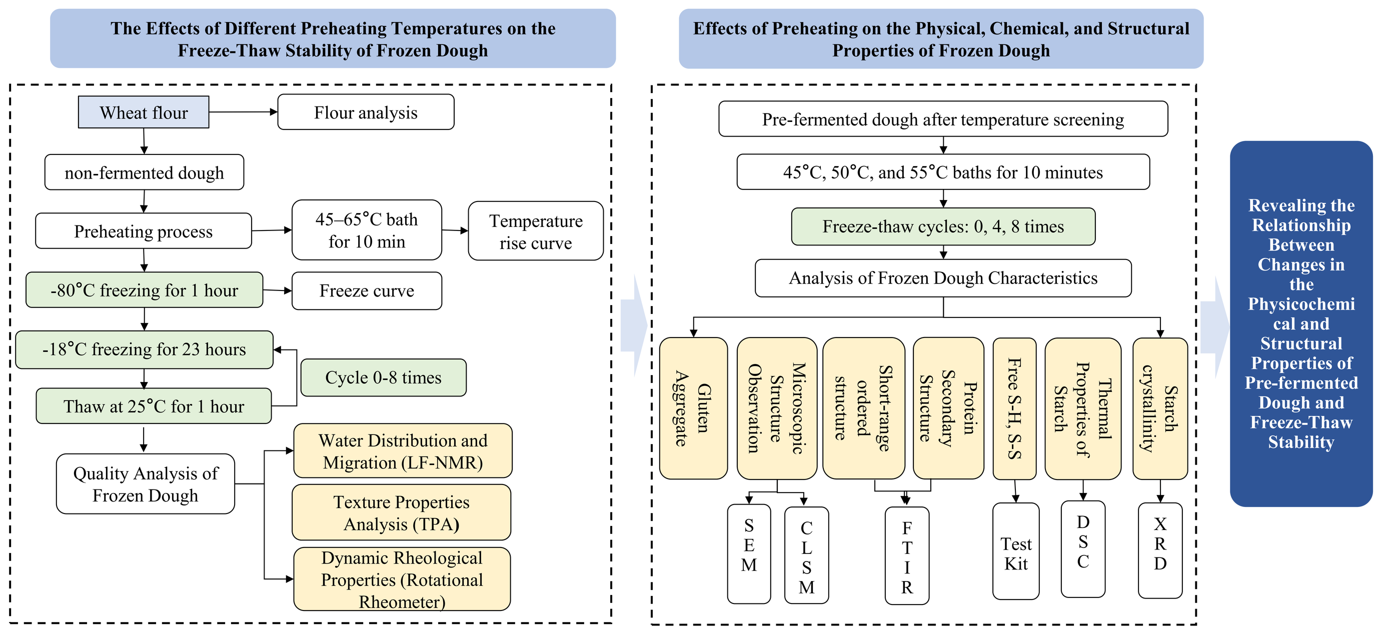
Research gap

There is limited research on improving the stability of frozen non-fermented dough using preheating processes.

Scientific question

The patterns of changes in various dough components and the related mechanisms remain to be revealed.

Technical Route



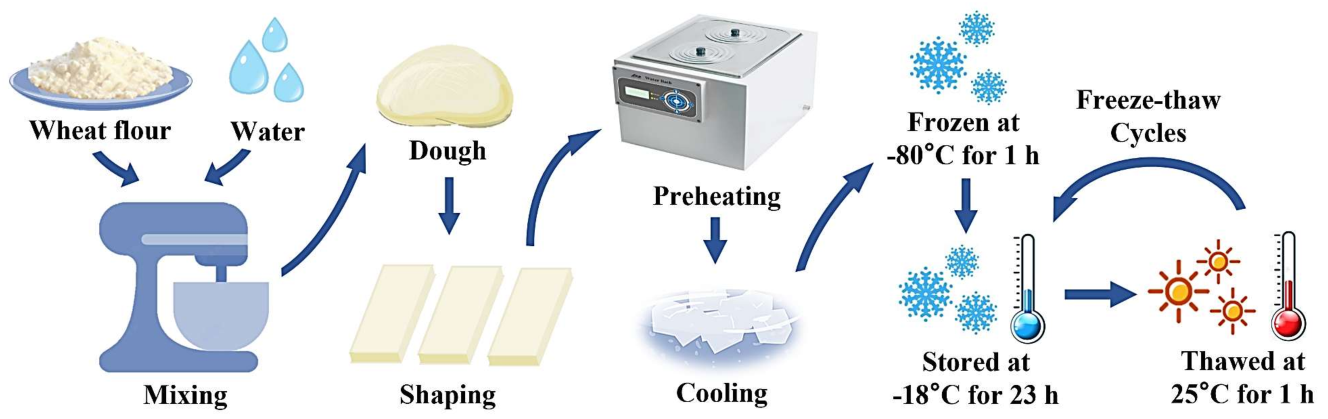
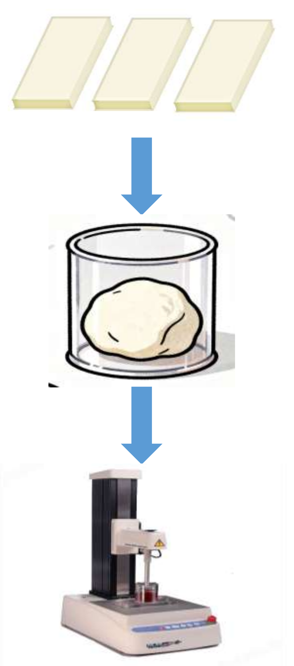


Fig. 1. Flow diagram of frozen dough preparation

Results

1. Dough properties analysis

1.1 Textural properties



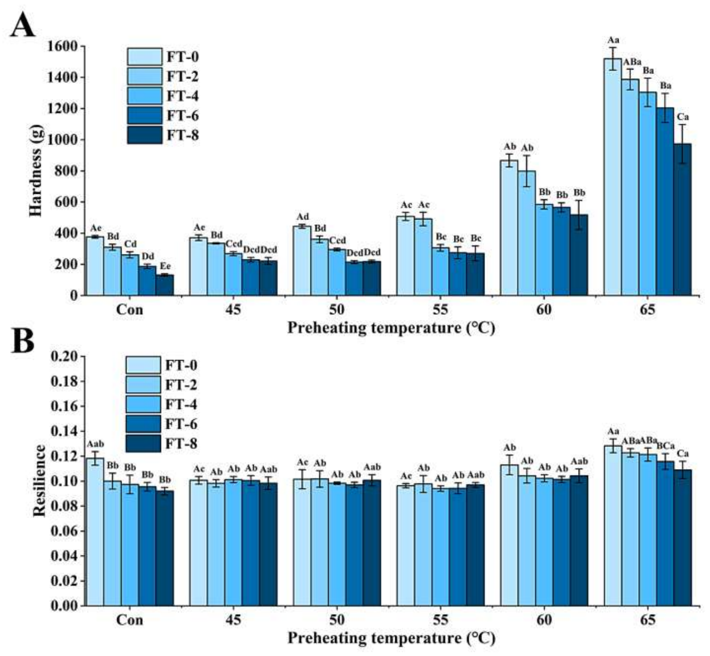


Fig. 1. Hardness (A) and resilience (B) of frozen dough at various preheating temperatures and FT cycles.

1.2 Dynamic rheological properties

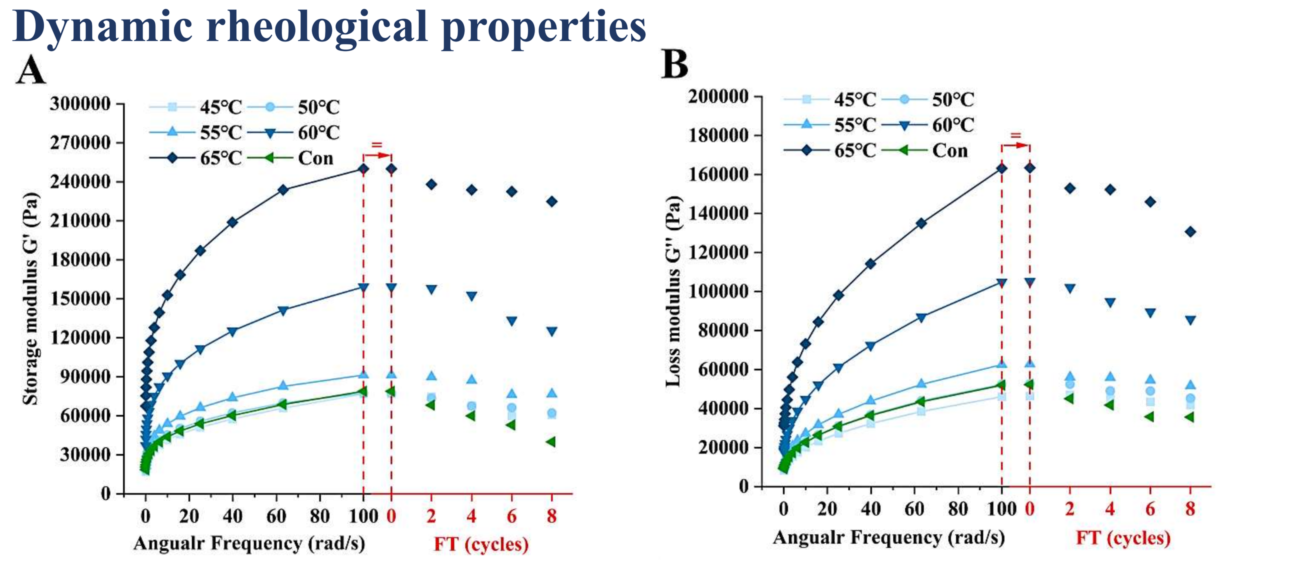


Fig. 2. Storage modulus (G′) (A) and loss modulus (G″) (B) of frozen dough at various preheating temperatures and FT cycles.

1.3 Water distribution and migration

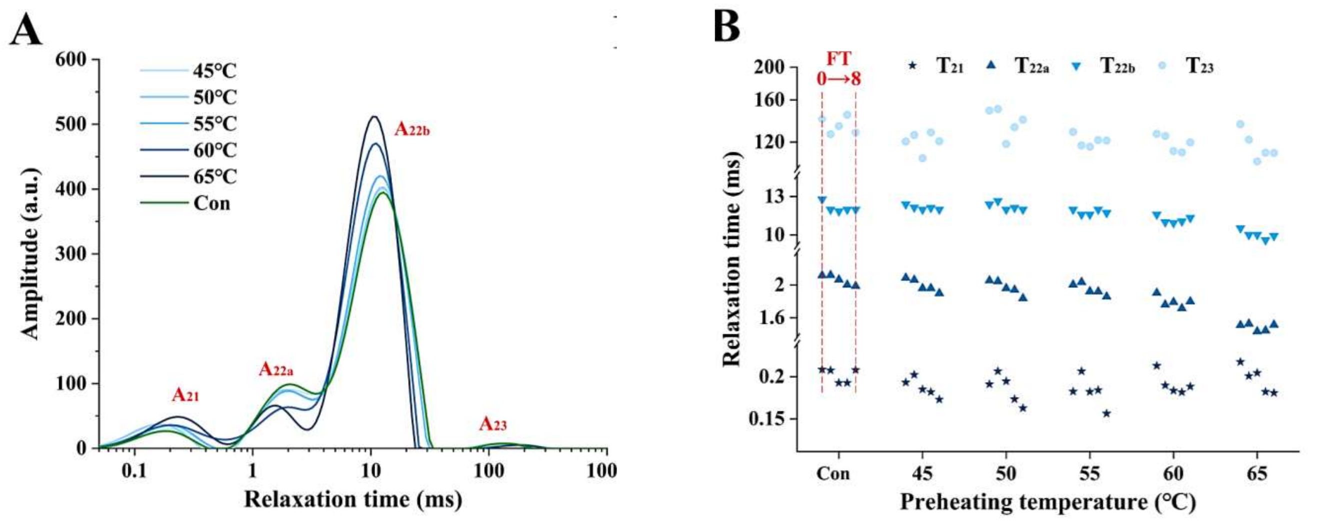


Fig. 3. (A) Relaxation time curves of unfrozen dough (FT-0) at various preheating temperatures. (B) Relaxation time of frozen dough at various preheating temperatures and FT cycles.

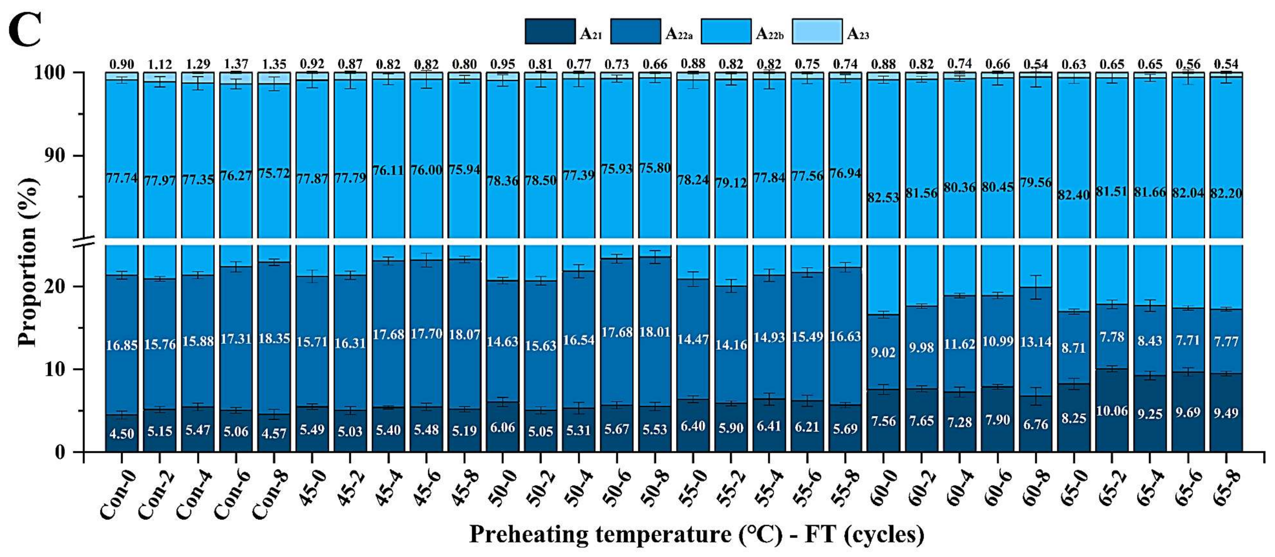


Fig. 4. (C) Proportion of water distribution in frozen dough at various preheating temperatures and FT cycles.

2. Dough starch multi-scale analysis

2.1 Thermal characteristic

Table 1 Thermal characteristic parameters of frozen dough at various preheating temperatures and FT cycles.

Preheating temperature(°C)	FT (cycles)	T_0(°C)	T_p(°C)	T_c(°C)	ΔH(J/g)	DO value
	0	56.53 ± 0.15 Cb	62.58 ± 0.08 Ca	76.68 ± 0.13 Cc	4.09 ± 0.07 Cb	1.013 ± 0.029 Bb
Con	4	56.95 ± 0.08 Bb	62.60 ± 0.07 Bab	79.05 ± 0.29 Bab	4.65 ± 0.13 Ba	1.196 ± 0.032 Aa
	8	57.46 ± 0.04 Ab	63.20 ± 0.17 Aa	80.94 ± 0.07 Aa	5.31 ± 0.18 Aa	1.248 ± 0.030 Aa
	0	56.46 ± 0.18 Bb	62.14 ± 0.02 Bb	77.56 ± 0.43 Cb	4.12 ± 0.13 Bb	1.000 ± 0.028 Bb
45	4	56.68 ± 0.18 Bb	62.42 ± 0.06 Bb	78.59 ± 0.28 Bb	4.45 ± 0.13 ABa	1.059 ± 0.011 Bb
	8	57.41 ± 0.07 Ab	63.06 ± 0.15 Aa	80.41 ± 0.32 Ab	4.58 ± 0.16 Ab	1.178 ± 0.007 Aab
	0	57.01 ± 0.05 Bb	62.82 ± 0.02 Aa	78.02 ± 0.18 Cb	4.47 ± 0.05 Aa	1.049 ± 0.032 Bb
50	4	57.07 ± 0.04 Bb	62.89 ± 0.09 Aa	79.44 ± 0.36 Ba	4.55 ± 0.08 Aa	1.097 ± 0.005 ABab
	8	57.81 ± 0.23 Ab	62.92 ± 0.09 Aa	80.68 ± 0.06 Ab	4.62 ± 0.07 Ab	1.146 ± 0.018 Ab
	0	57.77 ± 0.23 Ba	62.69 ± 0.18 Aa	78.92 ± 0.03Ba	4.49 ± 0.04 Ba	1.130 ± 0.006 Aa
55	4	58.09 ±0.24 Aba	62.81 ± 0.20 Aa	79.43 ± 0.16Aa	4.80 ± 0.05 Aa	1.049 ± 0.055 Ab
	8	58.69 ± 0.18 Aa	63.05 ± 0.26 Aa	79.60 ± 0.16Ac	4.84 ± 0.09 Ab	1.136 ± 0.048 Ab

2.2 Crystal structure and short-range ordering

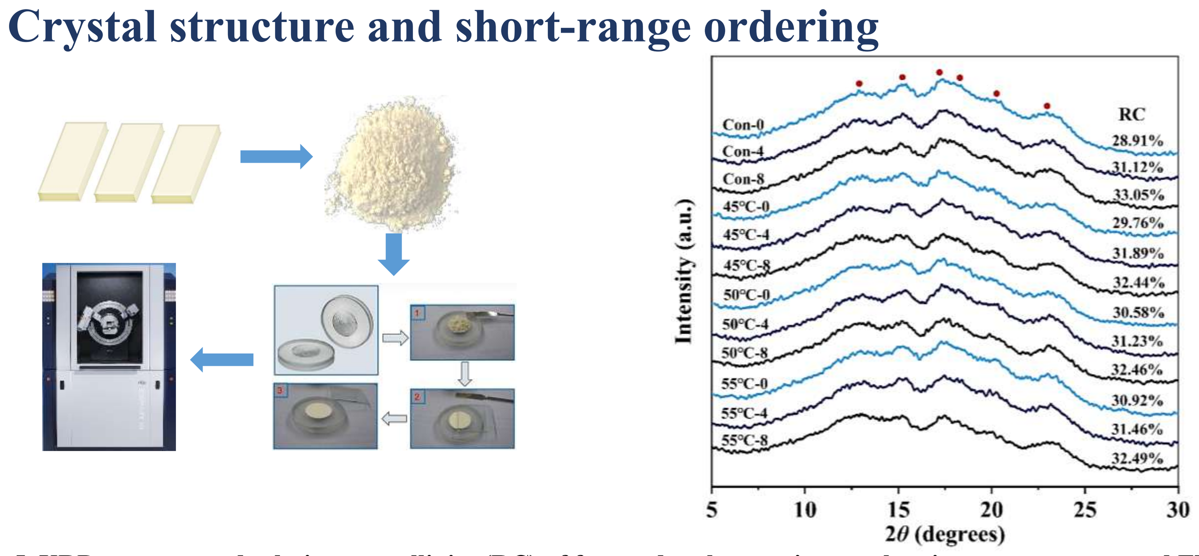


Fig. 5. XRD patterns and relative crystallinity (RC) of frozen dough at various preheating temperatures and FT cycles.

3. Dough gluten protein analysis

3.1 Glutenin macropolymer (GMP) wet weight

Table 2 Glutenin macropolymer (GMP) wet weight and free sulfhydryl (-SH) content of frozen dough at various preheating temperatures and FT cycles.

Preheating temperature (°C)	FT (cycles)	GMP wet weight (g/g)	-SH content (μM/g)
Con	0	0.876 ± 0.011 Ab	14.492 ± 0.053 Ca
	4	0.793 ± 0.021 Bc	16.762 ± 0.191 Ba
	8	0.640 ± 0.007 Cb	18.871 ± 0.308 Aa
45	0	0.948 ± 0.004 Aa	14.091 ± 0.022 Cb
	4	0.932 ± 0.011 Ab	15.906 ± 0.240 Bb
	8	0.691 ± 0.024 Bb	17.013 ± 0.272 Ab
50	0	0.952 ± 0.019 Aa	13.692 ± 0.081 Cc
	4	0.924 ± 0.015 Ab	15.681 ± 0.067 Bb
	8	0.783 ± 0.011 Ba	16.335 ± 0.369 Ac
55	0	0.993 ± 0.022 Aa	13.339 ±0.079 Bd
	4	0.979 ± 0.008 Aa	15.519 ±0.070 Ab
	8	0.807 ± 0.032 Ba	15.644 ±0.173 Ad

3.2 Free sulfhydryl (-SH) content

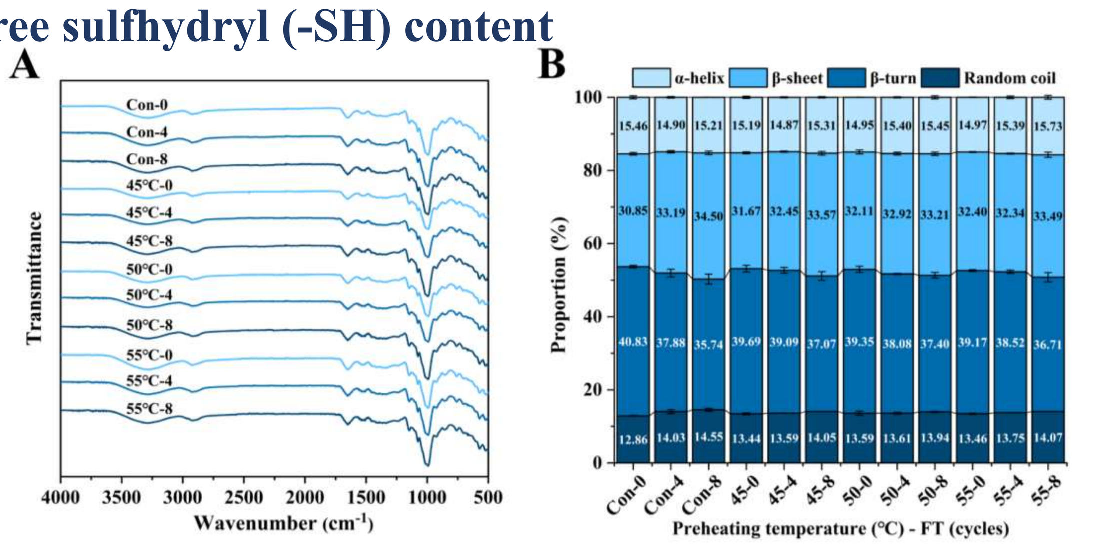


Fig. 6. FTIR spectra (A) and secondary structure proportion (B) of frozen dough at various preheating temperatures and FT cycles.

4. Microstructure analysis

4.1 SEM

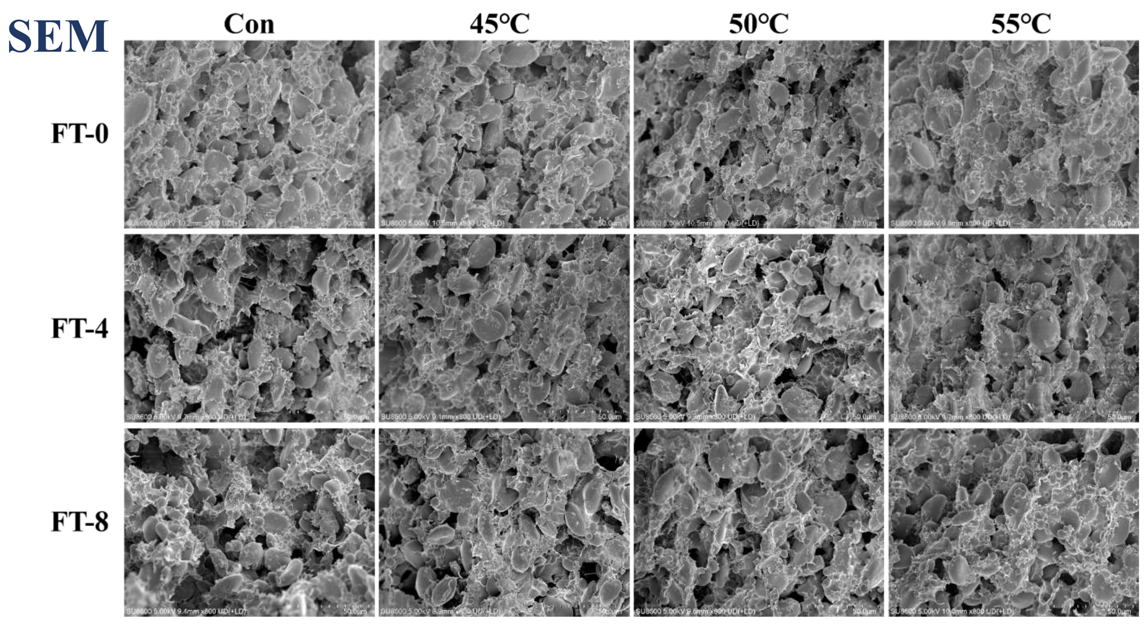


Fig. 7. SEM images of frozen dough at various preheating temperatures and FT cycles.

4.2 CLSM

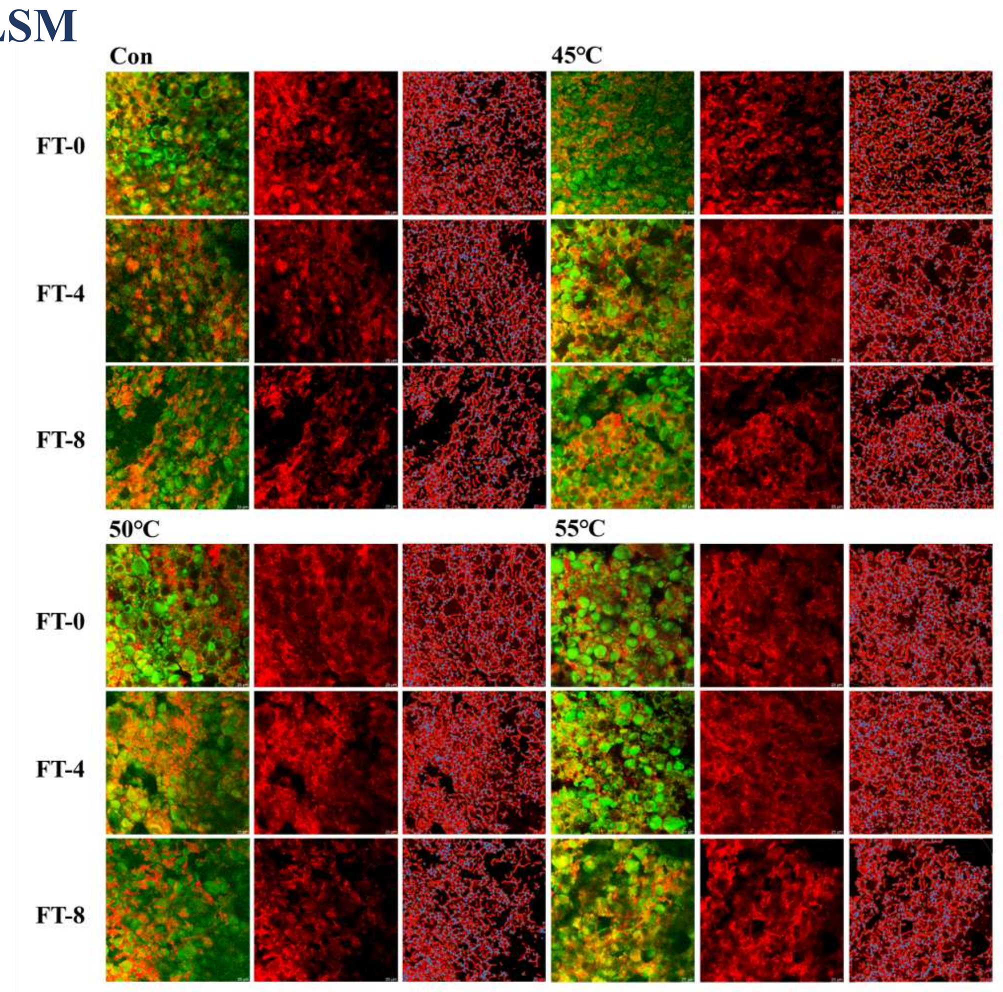


Fig. 8. CLSM images and protein network analysis of frozen dough at various preheating temperatures and FT cycles.

Conclusions and Prospects

Conclusions

1. Repeated FT cycles significantly **destroyed the texture of the dough**, resulting in decreased hardness, resilience, G′ and G″.
2. FT cycles led to the **migration and redistribution of water within the dough.**
3. FT cycles enhanced **the stability of protein network structures.**
4. Preheating at 50°C and 55°C **improved the FT stability of non-fermented dough** by promoting gluten-starch interactions, minimizing water migration, slowing the increase in starch crystallinity, and preserving a dense gluten protein network.

Prospects

Future research should investigate **the synergistic effects** of preheating in conjunction with **additives.**

Achievement

2025 Chinese University Life Science Competition the national 3th Prize(Innovation and entrepreneurship)

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