Study of hot air assisted radio frequency (HARF) drying and roasting of shelled peanuts

熱風輔助射頻乾燥和烘烤帶殼花生之研究

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大綱

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帶殼花生 Peanuts (*Arachis hypogaea*)

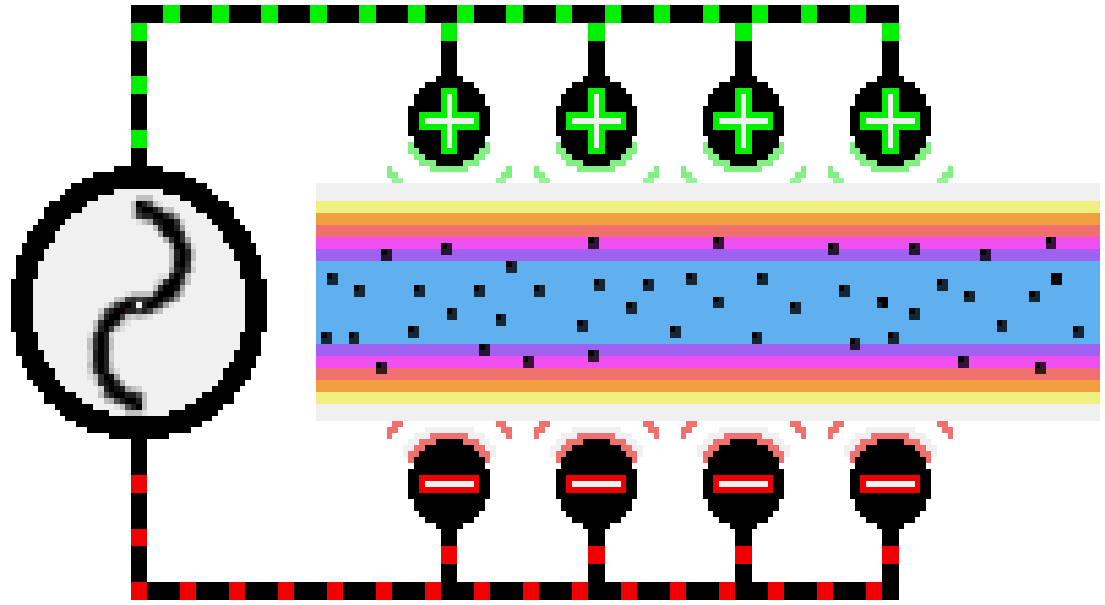
https://kknews.cc/zh-mo/health/2qabjge.html

- 鮮採帶殼花生的水分含量約為40%，日晒需要7~10天將水分含量降低於15%，以避免儲藏時微生物滋生，甚至產生致癌性黃麴毒素。

(Sahdev *et al.*, 2015)

射頻加熱Radio frequency (RF) heating

- 產熱機制為在食品內的極性水分子旋轉共振和離子快速移動而摩擦生熱。
- RF：13.56, 27.12 and 40.68 MHz
- MW：915 and 2450 MHz



(http://www.willems-ip.com/high-frequency-hf-technique/technologie/?lang=en)

連續式熱風輔助射頻加熱系統
Continuous HARF heating system

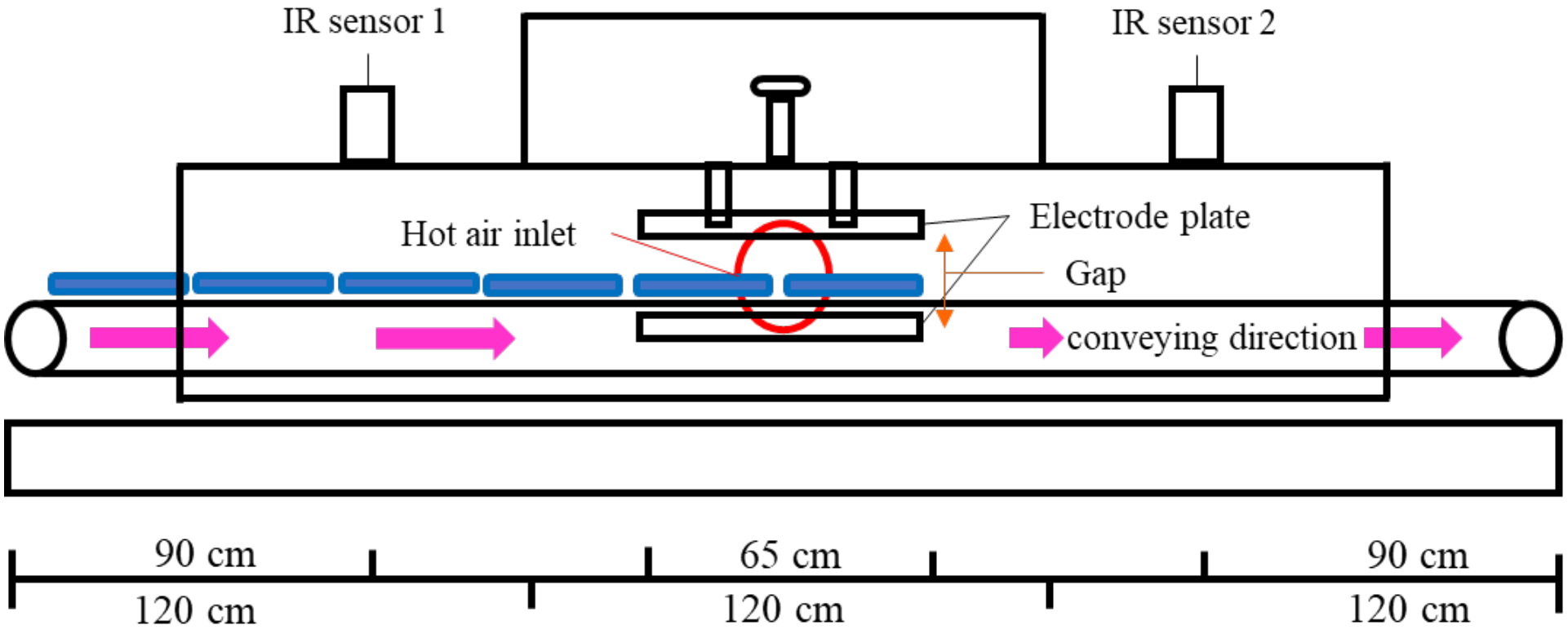


Table 1. Basic quality parameters of raw peanuts, hot air-assisted RF-roasted, and conventional oven-roasted peanuts

	Raw	RF roasting	Oven roasting*
Moisture content (%)	7.7±0.1^{a}	3.1±0.4^{b}	3.1
Acid value (mg/g)	0.25± 0.01^{a}	0.26±0.02^{a}	0.35
POV (meq/kg)	3.30± 0.06^{a}	2.46±0.10^{b}	6.02

Means in the same row with different lowercase letters were significantly different ($P<0.05$).

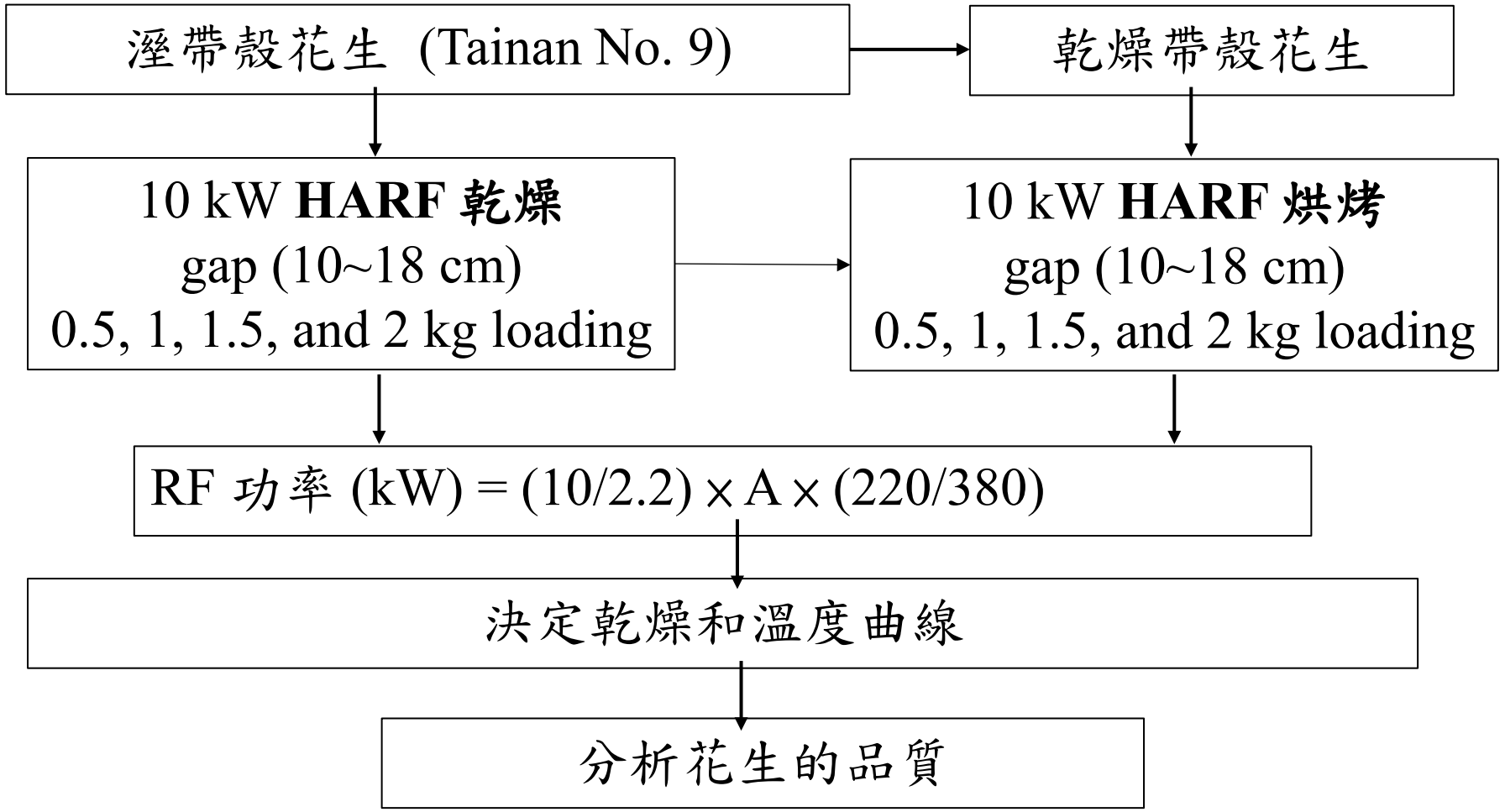
*Adopted from Zhoa (2010)

(Jiao *et al.*, 2016)

目的

- 利用熱風輔助10 kW, 40.68 MHz射頻設備乾燥和烘烤剛採收清洗的帶殼花生製程，並分析其品質，以期達到花生乾燥不落地，且又能省時節能減碳的目標。
- 研究熱風輔助10 kW, 40.68 MHz射頻設備烘烤已經日曬乾燥的帶殼花生的製程。

實驗設計


溼帶殼花生 (Tainan No. 9)
乾燥帶殼花生
10 kW HARF 乾燥
gap (10~18 cm)
0.5, 1, 1.5, and 2 kg loading
10 kW HARF 烘烤
gap (10~18 cm)
0.5, 1, 1.5, and 2 kg loading
RF 功率 (kW) = (10/2.2) × A × (220/380)
決定乾燥和溫度曲線
分析花生的品質

結果和討論

- HARF烘烤已經日曬乾燥的帶殼花生製程 (期中)
- HARF乾燥和烘烤剛採收清洗的帶殼花生製程 (期末)

結果和討論

HARF烘烤已經日曬乾燥的帶殼花生製程

（期中報告）

結果和討論

HARF roasting dried shelled peanuts

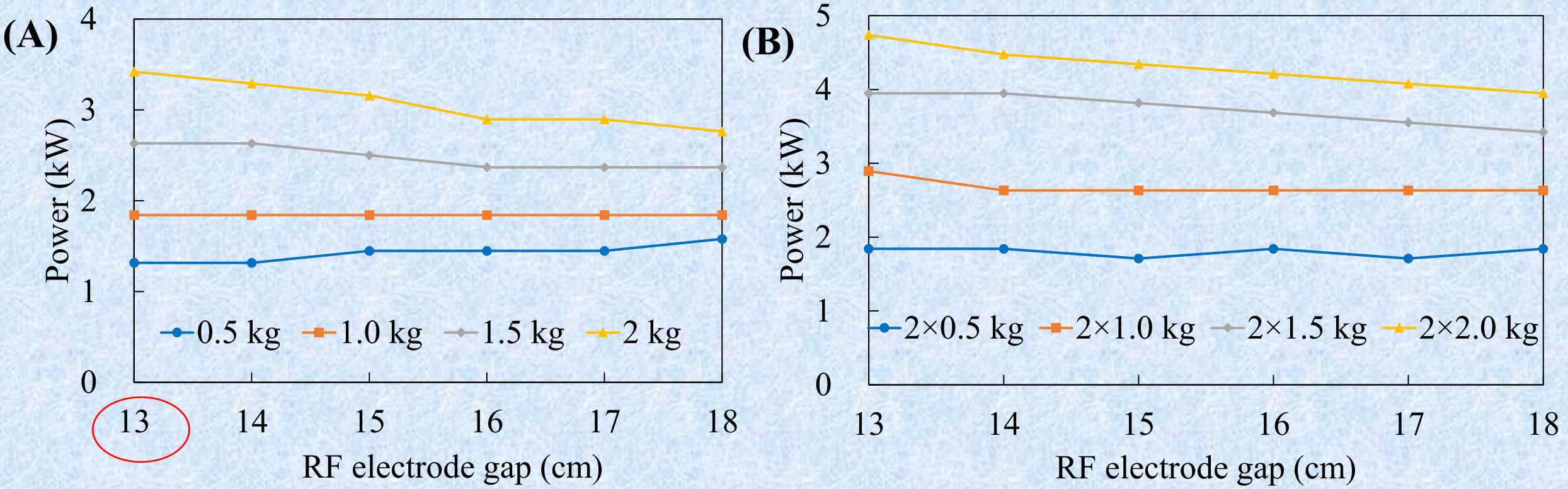


Fig. 5-1、Effect of shelled peanuts loading and RF electrode gap on RF power. (A) One bucket (B)Two buckets.

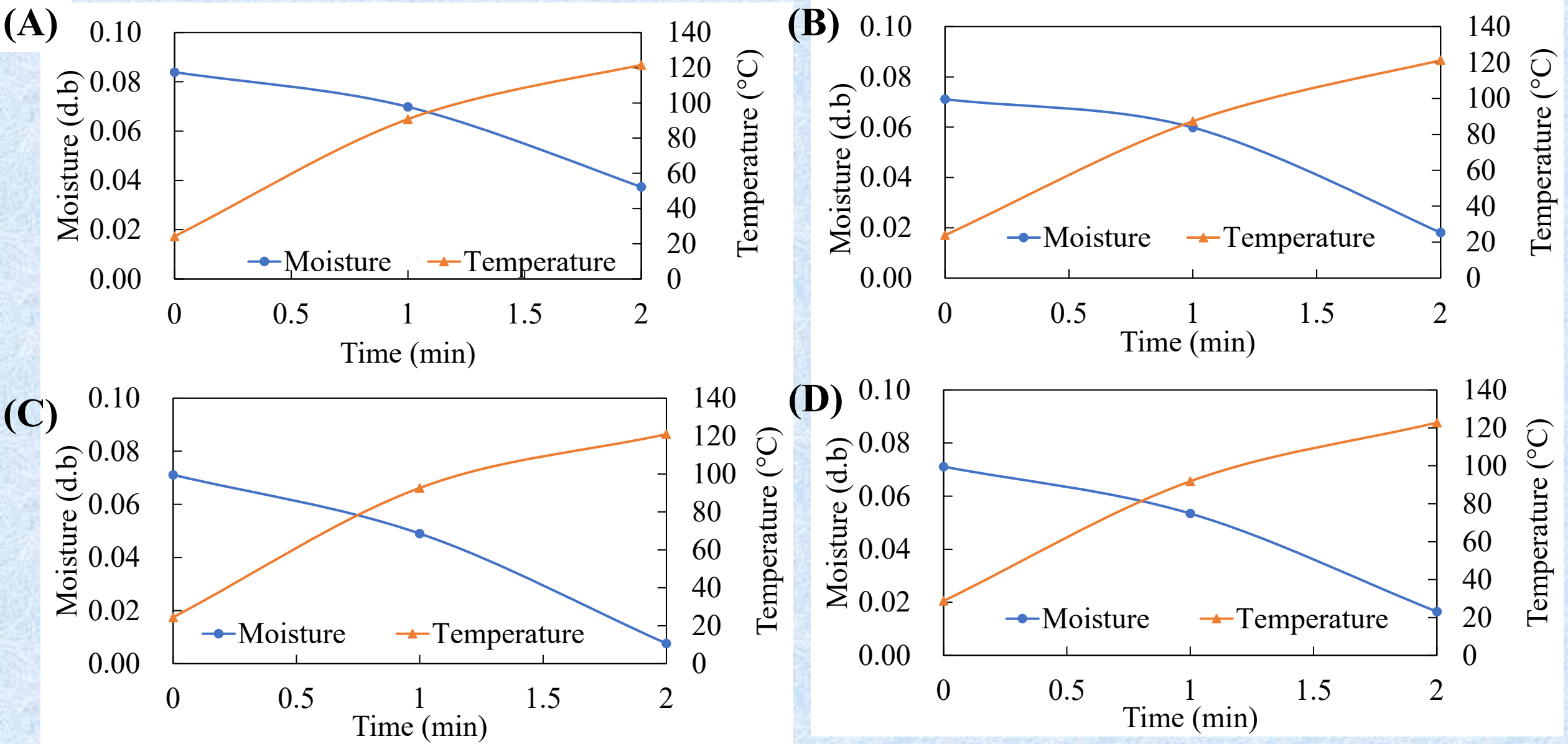


Fig. 5-2. The drying and temperature curves of HARF roasting at gap of 13 cm (A) 0.5 kg, (B) 1 kg, (C) 1.5 kg, and (D) 2 kg shelled peanuts.

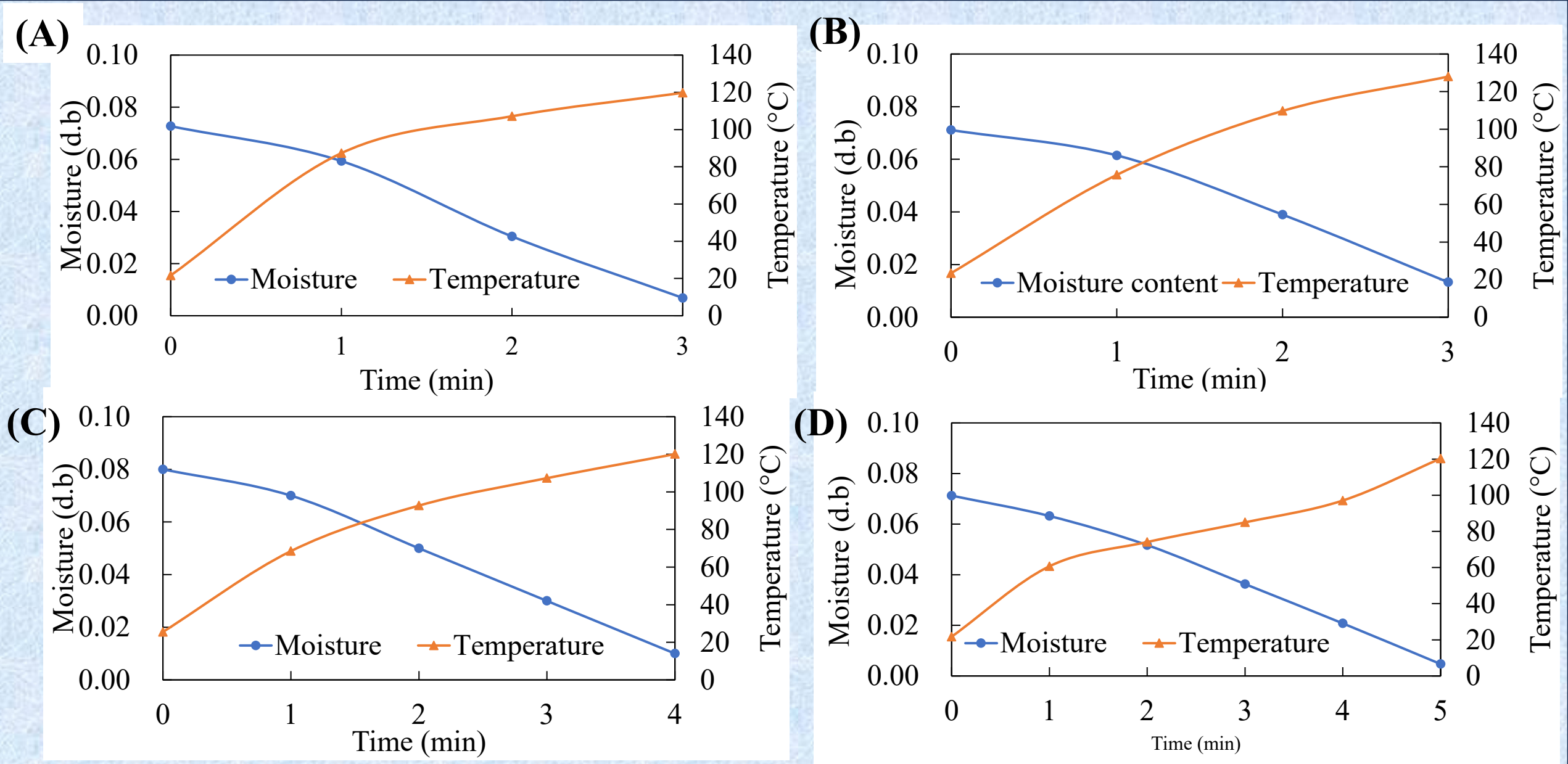


Fig. 5-3. The drying and temperature curves of HARF roasting at gap of 13 cm (A) 2x0.5 kg, (B) 2x1 kg, (C) 2x1.5 kg, and (D) 2x2 kg shelled peanuts.

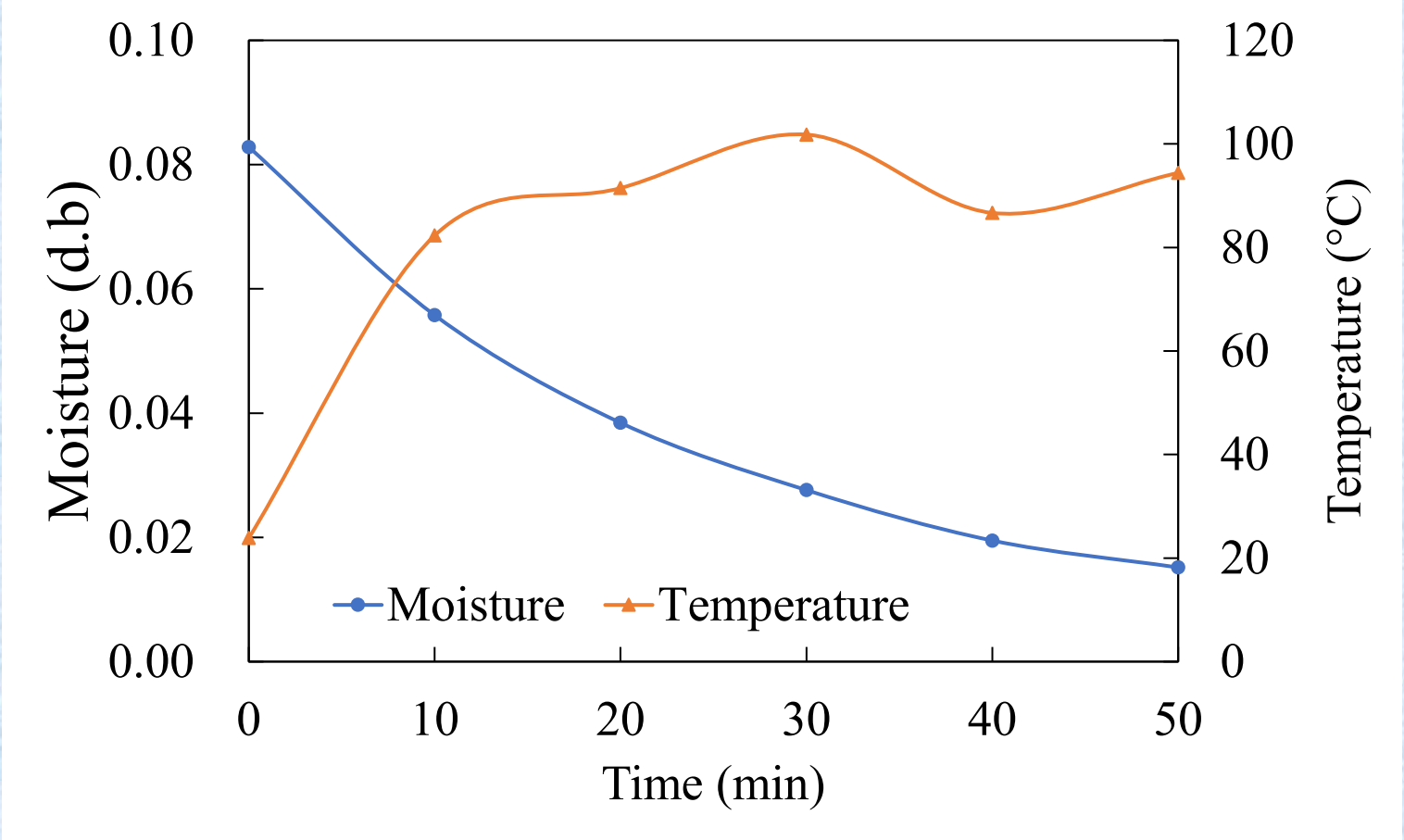


Fig. 5-4. The drying and temperature curves of 120℃ hot air circulation oven roasting 1kg shelled peanuts.

Table 5-1. The roasting time and energy consumption of roasting shelled peanuts

Loading of shelled peanuts (kg)	Condition	Gap (cm)	Time (min)	Energy consumption (kW·h)/kg
1.0	HARF	13	2	0.35
1.5	HARF	13	2	0.30
1.5	HARF	14	4	0.49
2×1.0	HARF	13	3	0.33
2×1.5	HARF	13	4	0.37
2×1.5	HARF	14	4	0.34
1.0	Oven	-	50	0.91

HARF: 100℃ hot air radio frequency.

Oven: 120℃.

Table 5-2. The quality analyses of roasted shelled peanuts

Items		Raw	Commercial	Oven	bRF-13-1.5 kg	bRF-13-2×1.5 kg
MC (%)		6.64±0.06 ^{a}	2.43±0.02 ^{d}	2.59±0.04 ^{cd}	2.63±0.02 ^{bc}	2.79±0.20 ^{b}
Aw		0.58±0.00 ^{a}	0.28±0.01 ^{d}	0.28±0.01 ^{d}	0.33±0.02 ^{b}	0.31±0.01 ^{bc}
Color	L*	27.44±3.35 ^{a}	17.05±2.92 ^{c}	24.28±2.44 ^{b}	24.06±2.86 ^{b}	24.12±1.79 ^{b}
	a*	8.72±0.83 ^{c}	12.17±1.18 ^{a}	11.52±0.97 ^{ab}	9.44±1.05 ^{c}	11.17±1.09 ^{b}
	b*	12.21±0.66 ^{b}	12.37±1.43 ^{b}	13.38±1.07 ^{a}	12.56±1.26 ^{a}	12.52±1.00 ^{a}
Hardness (N)		18.84±0.54 ^{a}	16.28±1.12 ^{b}	14.27±1.06 ^{c}	16.54±1.37 ^{b}	16.21±1.32 ^{b}
Fracturability (mm)		0.92±0.12 ^{a}	0.57±0.10 ^{b}	0.44±0.05 ^{c}	0.53±0.03 ^{b}	0.53±0.06 ^{b}
Scavenging DPPH free radicals (%)		94.92±0.18 ^{a}	93.53±0.23 ^{c}	92.37±0.13 ^{d}	93.67±0.07 ^{bc}	93.92±0.11 ^{b}

1. The Data of hardness, fracturability and DPPH were expressed as mean ± S.D. (n=10).
2. The others data were expressed as mean ± S.D. (n=3).
3. $^{a-d}$ Means with different superscript letter in the same row were significantly different ($p < 0.05$).
4. Scavenging of 20 mg/mL DPPH free radicals in the control group (%): 93.84±0.08.

Table 5-3. Sensory evaluation of roasted in-shell peanuts

Roasting	Appearance	Aroma	Flavor	Texture	Aftertaste	Overall
Commercial	6.93±1.28[a]	6.41±1.66[a]	6.89±1.38[a]	6.88±1.48[a]	6.71±1.56[a]	6.91±1.10[a]
Oven	6.63±1.61[a]	5.18±1.56[b]	5.54±1.86[b]	6.54±1.66[a]	5.66±2.13[b]	5.84±1.79[b]
bRF-13-2×1.5	6.63±1.61[a]	5.54±1.61[b]	5.73±1.74[b]	6.75±1.60[a]	6.00±1.72[b]	6.11±1.53[b]

Data were expressed as mean ± S.D. (n=56).

[ab] Means with different superscript letter in the same row were significantly different ($p < 0.05$).

b-RF-13-2×1.5: Batch radio frequency, Gap 13 cm, 2×1.5 kg.

Fig. 5-6. Different treatment of peanuts (A) Raw, (B) Commercial, (C) Oven & (D) bRF-13-2×1.5.

結果和討論

HARF乾燥和烘烤剛採收清洗的帶殼花生製程

（期末報告）

HARF drying raw shelled peanuts

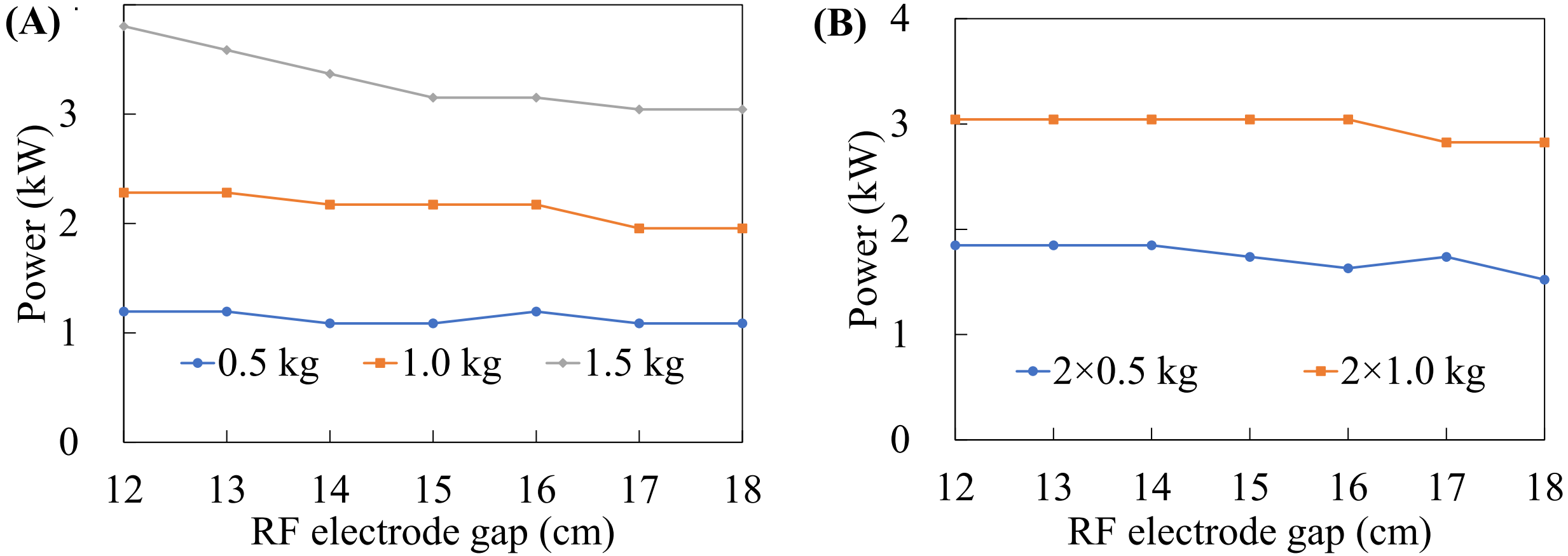


Fig. 4-1. Effect of loading and RF electrode gap on RF power. (A) One bucket (B)Two buckets.

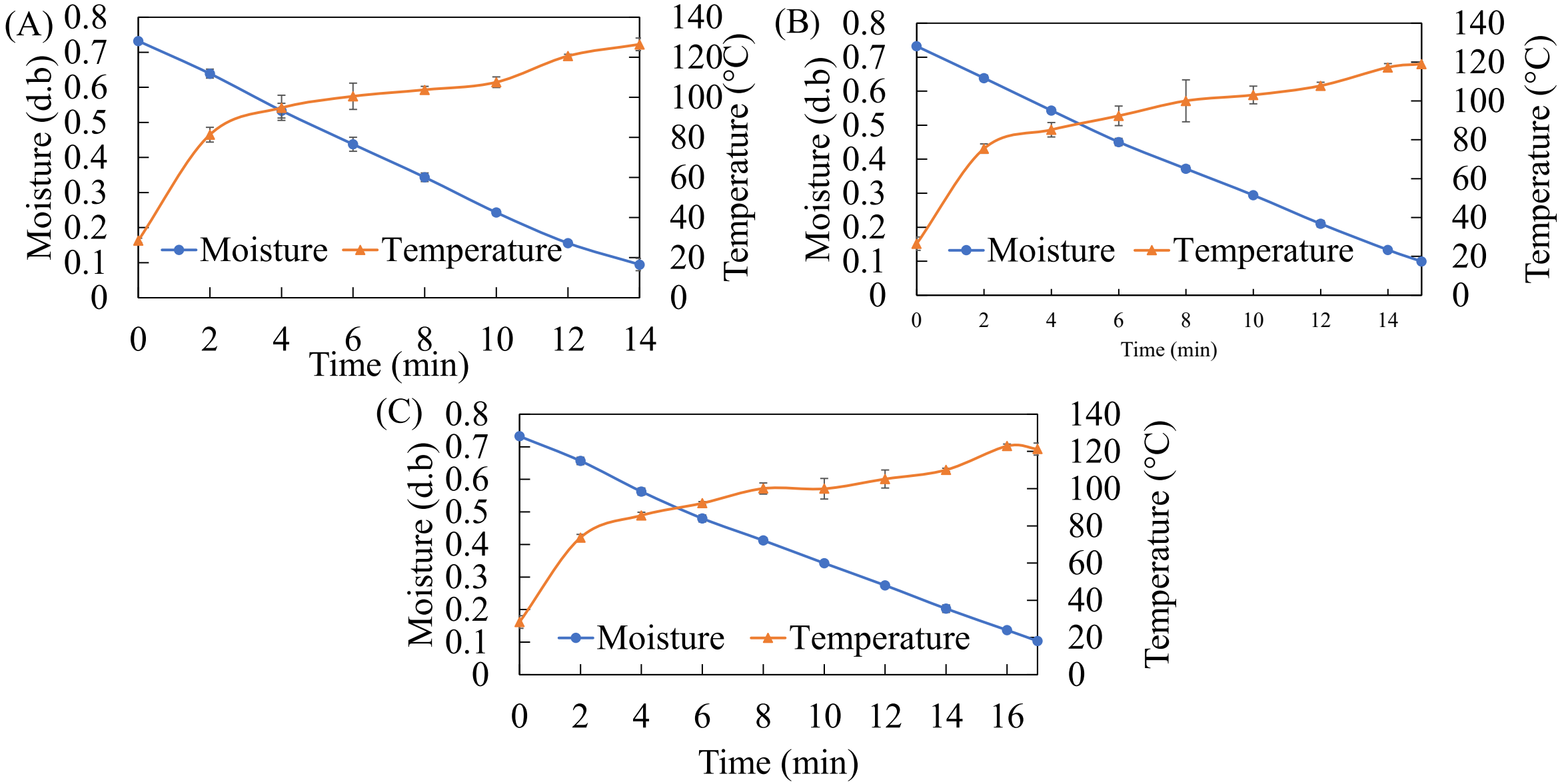


Fig. 4-2. Drying and temperature curves of 1 kg shelled peanuts during HARF drying at gap of (A)13, (B)15, and (C) 17 cm. (n=3)

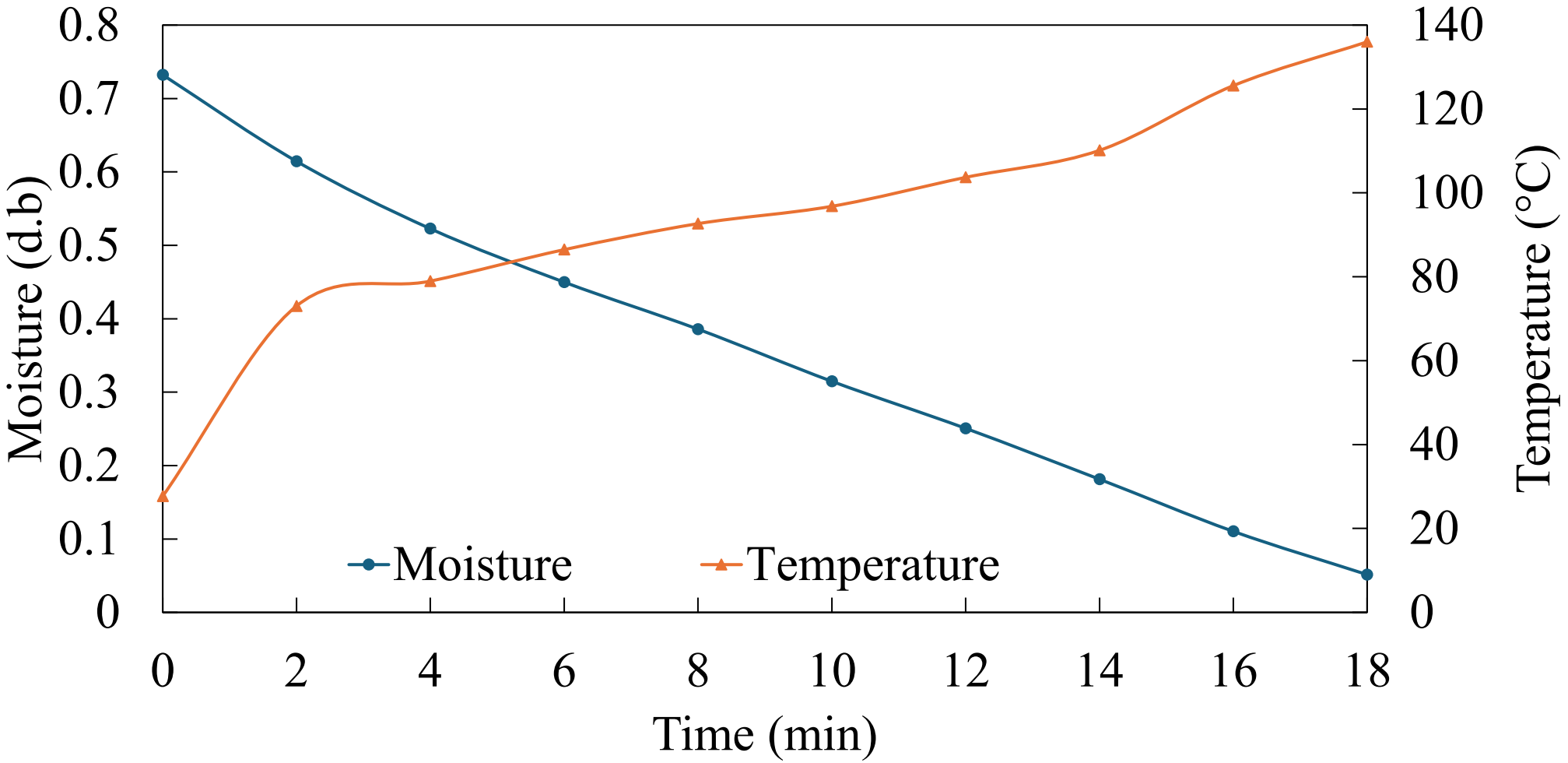


Fig. 4-5. Drying and temperature curves of 1 kg shelled peanuts during 10 kW, 40.68 MHz HARF drying and roasting at gap of 17 cm.

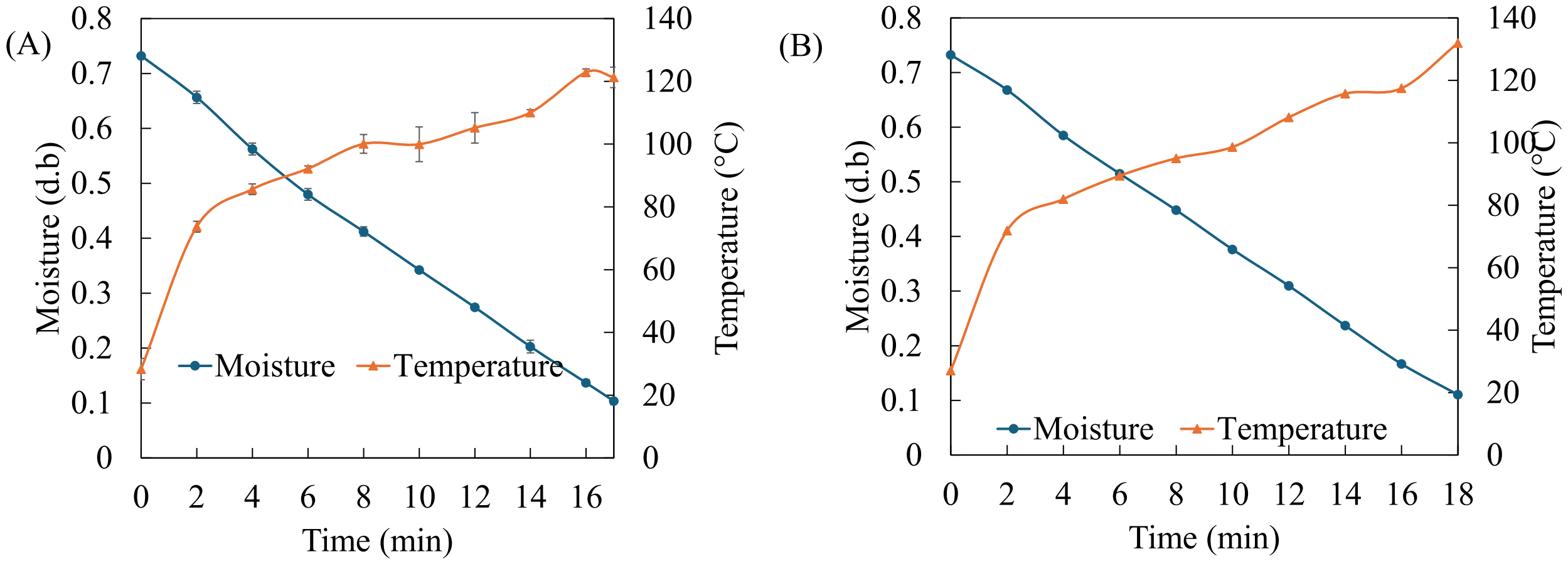


Fig. 4-6. Drying and temperature curves of 1 kg shelled peanuts (A) one bucket and (B) two buckets during 10 kW HARF drying and roasting at gap of 17 cm.

Table 4-1. Drying rate, drying time and energy consumption of 10 kW, 40.68 MHz HARF and cold air drying 1 kg raw fresh in-shell peanuts.

Drying method	Linear regression equation	R^2	Rate (g/min)	Time (min)	Energy consumption (kWh)/ kg
RF	y = -21.208x + 991.39	0.9974	21.21	17	2.18
Cold air	y = -0.813x + 926.75	0.8720	0.81	350	21.29

Table 4-2. Quality analyses of 10 kW, 40.68 MHz HARF in-shell peanuts

Item		SD-Raw	SD-RFR	FR-RFD	FR-RFDR
M. C. (%)		6.64±0.08 [a]	2.79±0.24 [c]	6.62±0.09 [a]	3.69±0.03 [b]
A_w		0.58±0.00 [a]	0.31±0.02 [b]	0.56±0.01 [a]	0.35±0.01 [b]
Color	L*	27.44±3.53 [a]	24.12±1.89 [b]	26.78±2.69 [a]	23.60±3.10 [b]
	a*	8.72±0.88 [b]	11.17±1.15 [a]	5.82±0.88 [c]	5.92±1.19 [c]
	b*	12.21±0.70 [a]	12.52±1.05 [a]	9.29±2.33 [b]	9.33±1.73 [b]
Hardness (N)		18.84±0.57 [c]	16.21±1.39 [c]	31.34±6.84 [a]	25.13±6.38 [b]
Fracturability (mm)		0.92±0.12 [a]	0.53±0.06 [c]	0.76±0.21 [b]	0.36±0.06 [d]
Scavenging DPPH (%)		94.92±0.22 [a]	93.72±0.13 [b]	94.72±0.24 [a]	94.89±0.27 [a]

1. The data of hardness, fracturability, and DPPH were expressed as mean ± S.D. (n=10).
2. The others data were expressed as mean ± S.D. (n=3).
3. [a-c] Means with different superscript letters in the same row were significantly different ($p < 0.05$).
4. Scavenging of 20 mg/mL DPPH free radicals in the control group (%): 93.84±0.08.

Table 4-3. Changes of acid and peroxide values of in-shell peanuts stored at 37°C

Peanuts storage at 37°C		0 day	10 days	20 days
Acid value	SD-Raw	0.153±0.006	0.157±0.000	0.155±0.001
	FR-RFD	0.157±0.000	0.156±0.000	0.155±0.001
	FR-RFDR	0.157±0.000	0.157±0.000	0.168±0.004
Peroxide value	SD-Raw	0.598±0.037	0.602±0.004	0.571±0.002
	FR-RFD	0.578±0.001	0.576±0.003	0.572±0.004
	FR-RFDR	0.578±0.001	0.576±0.002	0.631±0.017

Data were expressed as mean ± S.D. (n=3).
SD-Raw: Sun drying, Raw.
FR-RFD: Fresh raw, RF drying.
FR-RFDR: Fresh raw, RF drying & RF roasting.

Table 4-4、 Total count, yeast and mold and total Aflatoxin of different treated in-shell peanuts

Sample	AC (CFU/g)	YM (CFU/g)	Aflatoxin (B1, B2, G1 & G2)
FR	1.48×10^6	2.63×10^6	ND
SD-Raw	ND	ND	ND
SD-RFR	ND	ND	ND
FR-RFD	ND	ND	ND
FR-RFDR	ND	ND	ND

Data were expressed as mean ± S.D. (n=3).
ND = not detected.
AC: aerobic count; YM: yeast and mold count.

結 論

- 建立熱風輔助射頻乾燥新鮮帶殼花生操作製程一式，利用100℃熱風輔助10 kW, 40.68 MHz射頻加熱(HARF)系統在電極板間距17 cm下，1 kg帶殼花生(水分含量約為42%)只需17 min即可使溫度達到120℃，且水分含量10%以下，若持續再加熱1 min即可使溫度達到136℃以上，水分含量更降至3%的烘烤效果。相較於冷風乾燥需350 min，射頻乾燥可縮短約95%的乾燥時間和節省約90%能耗。
- 建立連續熱風輔助射頻烘烤帶殼花生操作製程一式，利用HARF在電極板間距13 cm下，1 kg已經日曬乾燥的帶殼花生在射頻電極板間距13 cm 烘烤下的加熱2 min時溫度可升至120℃，乾基水分含量可達0.04~0.01。若使用120℃旋風烤箱烘烤需50 min才使溫度僅升至100℃，比較兩種烘烤帶殼花生的烘烤時間和能源消耗，射頻烘烤只需2 min，每公斤約消耗0.3 kWh，相較旋風烤箱0.91 kWh, 50min，少了66.7%能耗，且時間節省約96%。
- 在37℃下真空包裝帶殼花生儲藏0、10和20天並無顯著差別，酸價約在0.15mg KOH/g，過氧化價約在0.6 meq/kg，此可能和真空包裝有關。另外經射頻加熱乾燥的帶殼，其剝殼後的花生仁，因經射頻快速高溫處理，並未檢出生菌數、酵母菌和黴菌，所以也未驗出黃麴毒素，提升花生的品質和衛生安定性。

Thank you for your attention !