Journal of Horticultural Research 2026, vol. 34(1): 93–104
DOI: 10.2478/johr-2026-0002

EFFECT OF BLANCHING METHODS ON CHLOROPHYLL CONTENT AND QUALITY CHANGES DURING FROZEN STORAGE OF COWPEA

Jinhua SHAO, Li YANG, Shuangle OUYANG, Qingmei ZENG, Zhiyong ZHU*, Liyan JIANG**
Hunan University of Science and Engineering, China

Received: April 2025; Accepted: January 2026

ABSTRACT

This study aims to explore ways to improve the postharvest green preservation of cowpea pods and subsequent quality changes during frozen storage. Chlorophyll content was the main evaluation indicator. In single-factor and orthogonal experiments, the best results were obtained by storing sliced pods at −20 °C after blanching them at 100 °C for 50 seconds in a mixture containing 0.09% baking soda and 1.5% soybean oil, with a solid-to-liquid ratio of 1 : 10. These conditions resulted in the highest chlorophyll and vitamin C content, reduced weight loss and decay rates, and superior sensory quality, significantly extending market quality from 15 to 25 days of storage.

Key words: green preservation, prefreezing, baking soda, soybean oil, *Vigna unguiculata*

INTRODUCTION

The cowpea (*Vigna unguiculata* (L.) Walp.), an annual herbaceous plant belonging to the Fabaceae family, is a crucial summer crop in China and is commonly known as the yardlong bean or asparagus bean (Wangmene et al. 2024). It is valued not only for its rich content of high-quality proteins, carbohydrates, vitamins, and trace elements (Luo et al. 2006; Wang et al. 2024) but also for its medicinal properties, such as strengthening the spleen, kidneys, and immunity (Zhang et al. 2023). However, due to its strong seasonality and regional dependence, the cowpea is highly perishable (Zhang 2008; Han et al. 2023). Without prompt postharvest preparation, the cowpea is susceptible to dehydration, discoloration, and rusting, significantly reducing its quality and economic value (Zhang 2008; Han et al. 2023). Therefore, developing effective preservation techniques is essential.

Various methods have been used to preserve cowpeas, including irradiation, chemical treatment, modified atmosphere storage, ozonation, and freezing (Zhang 2023; Simon et al. 2024; Duan et al. 2025; Li 2025; Li et al. 2025a). However, each of these methods has noticeable drawbacks. Irradiation and chemical treatment raise concerns about potential health risks and nutrient degradation (Xu 2024; Zhao et al. 2025). Modified atmosphere and ozone preservation techniques are limited by ineffective respiration control and strict temperature and humidity requirements (Tang 2016; Wei et al. 2024). Freezing, on the other hand, offers considerably longer storage times, making it particularly suitable for long-term storage (Wu et al. 2006). Studies indicate that blanching prior to freezing effectively preserves vitamin C, polyphenols, and chlorophyll in frozen vegetables (Favell 1998; Mazzeo et al. 2015).

Despite its advantages, freezing poses specific quality challenges. A key issue is the deterioration of the original texture upon thawing, especially for delicate vegetables (Baardseth 1978; Giannakourou & Taoukis 2003). Furthermore, color stability remains a significant concern, as vegetables often yellow during frozen storage or quick freezing due to chlorophyll degradation (Liu & Dong 2015). Therefore, effective prefreezing treatments are crucial to preserving both texture and color.

Research shows that texture, and particularly crispness, can be preserved using methods such as the addition of metal ions (e.g., calcium salts) (Fraeye et al. 2010; Krajewski et al. 2015) and heat treatments that activate endogenous pectin methylesterase (PME) (Abu-Ghannam & Crowley 2006; Wang et al. 2016; Zhang et al. 2017). These processes promote the formation of stable pectin salts,

Corresponding authors
e-mail: * zzyhnkjxy@163.com, ** lyj5423@163.com

thereby strengthening plant tissues (Li et al. 2018; Fraeye et al. 2010). To preserve color, a brief immersion in boiling water (blanching) is a key pretreatment that inactivates enzymes responsible for quality degradation. Although various prefreezing techniques exist, such as radiofrequency, ohmic, and far-infrared blanching, they often face limitations related to uneven heating, high cost, or potential texture softening (Xie et al. 2013a; Liu & Dong 2015; Zhang et al. 2015). In contrast, blanching at high water temperature ensures uniform heating regardless of sample shape, with minimal adverse effects on texture, making it a practical and effective option (Mandalari et al. 2006; Lyu et al. 2023).

Although blanching is widely known, the synergistic effect of combining it with specific additives, such as baking soda (an alkalizing agent) and soybean oil (a lipophilic agent), to enhance chlorophyll retention in cowpeas during freezing has not been thoroughly investigated. Therefore, this study aims to systematically assess the effect of key factors, such as baking soda and soybean oil concentration, solid-to-liquid ratio, and blanching time, on the green preservation of cowpeas, using chlorophyll content as the primary indicator. Furthermore, it compares the quality changes between blanched and unblanched cowpeas during frozen storage. The ultimate goal is to optimize a prefreezing protocol that effectively extends the shelf life of frozen cowpeas while maintaining sensory and nutritional quality.

MATERIALS AND METHODS

Fresh cowpeas (a local cultivar of *Vigna unguiculata*) were purchased at the Yangzitang Vegetable Market. Cowpeas were selected that were uniform in size, had a tender texture, were fresh and shiny, and were free from pests, diseases, and damage. They were thoroughly rinsed with distilled water and then placed in a well-ventilated area to air-dry naturally. After drying, they were cut into 3-cm long strips. For each treatment, the blanching solution contained distilled water and additives such as baking soda or soybean oil. Typically, 10 g of fresh cowpeas, prepared as above, were added, setting the solid-to-liquid ratio at 1 : 10 when the temperature reached 100 °C. After each experiment, chlorophyll was extracted and measured at 652 nm absorbance. All chemical reagents were of analytical grade.

Single-factor experiments

1. The experimental mixture contained 1% of soybean oil and baking soda at concentrations of 0.06%, 0.07%, 0.08%, 0.09%, and 0.10%. Samples were removed after 30 seconds and immediately cooled in ice water.
2. The experimental mixture contained 0.08% baking soda and soybean oil at concentrations of 1.0%, 1.5%, 2.0%, 2.5%, and 3.0%. Samples were removed after 30 seconds and immediately cooled in ice water.
3. The experimental mixture contained 0.08% baking soda and 2.0% soybean oil. Samples were removed after 30, 40, 50, 60, and 70 seconds and immediately cooled in ice water.
4. The experimental mixture contained 0.08% baking soda and 2% soybean oil. Cowpeas were blanched at various solid-to-liquid ratios: 1 : 6, 1 : 10, 1 : 14, 1 : 18, and 1 : 22, with the addition of 60, 100, 140, 180, and 220 mL of water, respectively. Blanching time was 60 seconds.

Orthogonal experiment

Based on the results of the single-factor experiments, an orthogonal experiment was conducted with 4 factors: A – baking soda addition (%), B – soybean oil addition (%), C – blanching time (s), and D – solid-to-liquid ratio, and with 3 factor levels (Table 1).

Validation experiment

To verify the validity of the optimal processing conditions determined by the orthogonal experiment, fresh cowpeas were blanched using an optimized combination of parameters (0.09% baking soda, 1.5% soybean oil, a solid-to-liquid ratio of 1 : 10, and 50 seconds of blanching) and then cooled. This experiment was conducted three times.

Table 1. Orthogonal experiment

Level	Factor			
	A – baking soda (%)	B – soybean oil (%)	C – blanching time (s)	D – solid-to-liquid ratio
1	0.07	1.5	50	1:6
2	0.08	2.0	60	1:10
3	0.09	2.5	70	1:14

Chlorophyll content measurement

The method for determining chlorophyll content described by Yan (2015) was slightly modified. Briefly, 1 g of cowpeas was weighed and ground to a uniform paste in a mortar with 5 mL of anhydrous ethanol and 1 g of quartz sand, then left to stand for 5 minutes. The mixture was filtered into a 50 mL volumetric flask and diluted to the mark with anhydrous ethanol. Absorbance was measured at 652 nm. The chlorophyll content (mg per 100 g) was calculated according to the following formula (1): Chlorophyll = $(A_{652} \times V)/(m \times 34.5) \times 100$; where V is the total filtrate volume (mL) and m is the cowpea mass (g).

Determination of vitamin C content

The method for determining vitamin C content described in GB 5009.86-2016 and by Okafor et al. (2024) was slightly modified. Briefly, 2 g of cowpeas were weighed and 5 mL of 20 $g \cdot L^{-1}$ oxalic acid solution and 1 g of quartz sand were added. The mixture was thoroughly ground to a uniform paste in an ice bath. The resulting solution was transferred to a 50 mL volumetric flask, together with three mortar washes with 20 $g \cdot L^{-1}$ oxalic acid solution. The flask was then filled to the mark and mixed thoroughly. The solution was allowed to stand at room temperature for 5 minutes, then filtered, and the filtrate was collected. A 10 mL aliquot of the filtrate was accurately measured into a conical flask and titrated with 2,6-dichlorophenolindophenol solution. The titration was considered complete when the solution turned slightly pink and remained stable for at least 30 seconds. The oxalic acid solution was used as a blank control. Vitamin C content (mg per 100 g) was calculated using the following formula (2): Vitamin C = $(V_1 - V_0) \times V \times \rho)/(m \times V_S) \times 100$; where V_1 – volume of 2,6-dichlorophenolindophenol solution consumed during titration of the sample (mL); V_0 – volume of 2,6-dichlorophenolindophenol solution consumed during the titration of the unblanched sample (mL); ρ – mass of vitamin C equivalent in 1 mL of 2,6-dichlorophenolindophenol solution (mg per mL); V_S – volume of filtrate used for titration (mL); m – mass of cowpea (g).

Determination of weight loss rate

The method described by Li et al. (2025b) was used to determine the rate of weight loss. The initial mass of each cowpea sample was set to 50 g. A total of 42 groups were included in the study: 21 control and 21 experimental. During storage, samples were collected every 5 days, measuring 3 samples at each time point from both the control and experimental groups, and each sample was measured three times. The weight loss rate (%) of cowpea was calculated according to the following formula (3): Weight loss = (initial mass − final mass)/initial mass × 100.

Determination of the decay rate

The method described by Liu et al. (2024) was used to determine the decay rate. During the storage period, the number of decayed cowpeas in each group was counted every five days. The decay rate (%) of cowpeas was calculated using the following formula (4): Decay = (number of decayed cowpeas)/(total number of stored cowpeas) × 100.

Sensory evaluation

The sensory evaluation method described by An et al. (2024) and Fernández-León et al. (2013) was used with minor modifications. The sensory evaluation panel consisted of 10 trained individuals (5 female and 5 male), and the evaluation was conducted at room temperature (23 °C ± 2 °C). Detailed sensory evaluation standards are shown in Table 2. The overall evaluation was based on the average score for each experimental group.

Table 2. Sensory evaluation standards

Score	Appearance of cowpea
9–10	Bright color, luster, crisp texture, no browning, perfect condition, commercial value and available for sale
7–8	Relatively vibrant color, odorless, no signs of browning, good quality, available for sale
6	Dull color, loss of shine, slight browning, slight odor, reduced commercial value and limited for sale
3–5	Dull and matte color, browning, noticeable thaw odor, decay and spoilage, unsaleable
1–2	Dull and lifeless color, severe browning, strong thaw odor, severe decay, unsaleable

Changes in cowpea quality during frozen storage after blanching

Cleaned and sliced cowpeas were divided into two groups: blanched and unblanched. The treated group received the optimal factors determined in the orthogonal experiment, while the control group received no treatment. Each 50-g group was then placed in polyethylene (PE) bags, sealed with two loops of rubber bands, and stored in a freezer at −20 °C. Every 5 days, the cell structure of the cowpeas in each group was observed under a microscope. A section of cowpea (approximately 0.5 cm^2) was cut with a razor blade. The epidermis was then carefully peeled off with forceps, immersed in a drop of water on a glass slide, and gently flattened. The coverslip was lifted with forceps, initially placing one edge in contact with the drop water on the glass slide, and slowly lowered to cover the sample. The microstructure of cowpeas was observed under a microscope using a 10× objective lens. Sensory evaluation was conducted, and the weight loss rate, decay rate, chlorophyll content, vitamin C content, and other indicators of cowpeas in each group were measured.

Data analysis

All experiments were repeated three times, and data are presented as mean ± standard deviation. Data analysis was performed using the STDEV.P function in Excel to calculate standard deviation. Graphs were generated using Origin Pro 2021, and all significance analyses were performed using IBM SPSS Statistics 24.0. A one-way analysis of variance (ANOVA) was performed on the chlorophyll content data obtained from each single-factor experiment. When the ANOVA results indicated significant differences ($p < 0.05$), the Tukey's honestly significant difference (HSD) post hoc test was used for pairwise comparisons at multiple levels. The level of significance was set at $p < 0.05$.

RESULTS AND DISCUSSION

Baking soda effect

Chlorophyll content initially increased with baking soda concentration up to 0.08% and then decreased (Fig. 1). This may be attributed to the ester groups present in the chlorophyll structure. In alkaline baking soda, the ester groups saponify, forming alkaline chlorophyll salts, which help stabilize it (Gugouch & Elghorba 2024). However, as the baking soda concentration increases further, saponification produces soap particles that can adsorb some of the chlorophyll, leading to a decrease in its concentration (Huang 2022). Therefore, to maintain the quality of cowpeas, the amount of baking soda must be strictly controlled.

Soybean oil effect

Chlorophyll content increased up to 2% of the oil and then decreased (Fig. 2). This may be due to the increased release of chlorophyll, a fat-soluble pigment, after the addition of oil. However, this effect is limited to a certain extent (Bianchi et al. 2015). Appropriate addition of soybean oil significantly improves cowpea quality.

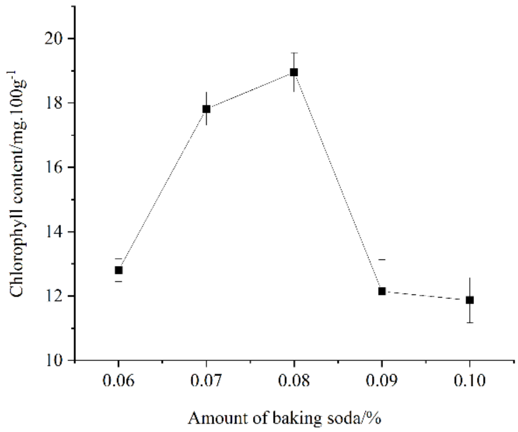

Figure 1. Effect of different concentrations of baking soda on the chlorophyll content in blanched cowpeas
Vertical lines represent SD for n = 3

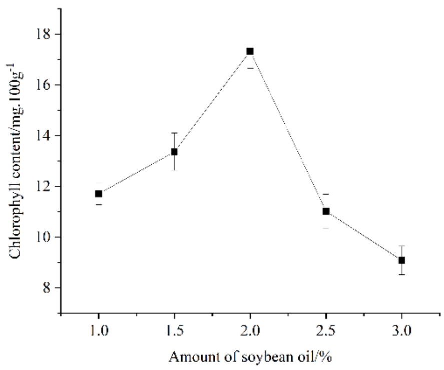

Figure 2. Effect of different soybean oil concentrations on chlorophyll in blanched cowpeas
Vertical lines represent SD for n = 3

Effect of blanching time

Chlorophyll content initially increased up to 60 seconds and decreased with increasing blanching time (Fig. 3). This may be due to disruption of the chlorophyll structure during blanching, which leads to the release of a substantial amount of free chlorophyll. The decrease in chlorophyll content during blanching should be similar to the degradation of chlorophyll by heat (Lípová et al. 2010). Prolonged exposure to heat accelerates degradation and promotes the conversion of chlorophyll to pheophytin, causing a color to change from the original shiny green to a dull yellow and a complete loss of luster (Kong et al. 2023).

Effect of solid-to-liquid ratio on chlorophyll content

Of the solid-to-liquid ratios tested, a 1 : 10 ratio proved most effective, with both lower and higher ratios resulting in lower chlorophyll content (Fig. 4). However, as water content increased, chlorophyll content began to decline, which may be related to its release into the mixture. With a smaller solution, the cowpea concentration gradient is greater, leading to higher chlorophyll content. However, with a higher solution concentration, the concentration gradient is smaller, leading to lower chlorophyll content. Furthermore, excessive use of the solution leads to waste (Guo et al. 2007; Xie et al. 2013a).

Results of the orthogonal experiment

Based on the results of the single-factor experiments, a three-level orthogonal experiment was conducted using chlorophyll content as the evaluation measure (Table 3). It can be seen that factor B has the greatest influence on the preservation of the green color of cowpeas, followed by factors C and A, and factor D has the least influence. The optimal preservation process for cowpeas is A3B1C1D2, which corresponds to the addition of 0.09% baking soda, 1.5% soybean oil, a blanching time of 50 seconds, and a solid-to-liquid ratio of 1 : 10.

Verification experiment

Optimal process conditions, determined in an orthogonal experiment, were used to blanch cowpeas three times. The experimental results indicated that the chlorophyll content of the blanched cowpeas was 20.87 ± 0.033 mg per 100 g.

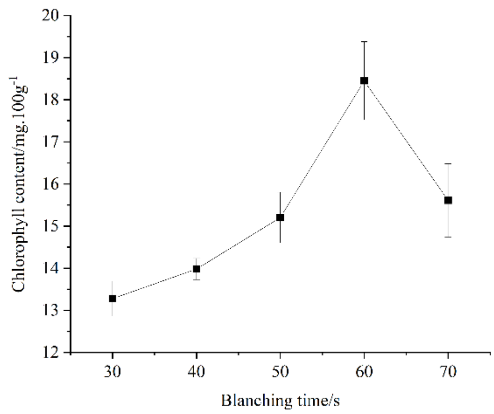

Figure 3. Effect of different blanching times on chlorophyll content in blanched cowpeas

Vertical lines represent the SD for n = 3

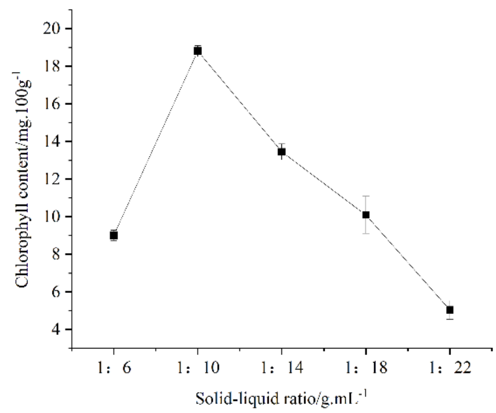

Figure 4. Effect of different solid-to-liquid ratios on chlorophyll content in blanched cowpeas

Vertical lines represent SD for n = 3

Table 3. Experimental design and signal-to-noise ratio expressed as chlorophyll content

Experiment	Factor				Signal-to-noise ratio
	A	B	C	D	
1	1	1	1	1	18.97±0.13
2	1	2	2	2	15.20±0.08
3	1	3	3	3	16.62±0.06
4	2	1	2	3	17.34±0.09
5	2	2	3	1	16.55±0.15
6	2	3	1	2	17.86±0.04
7	3	1	3	2	20.54±0.07
8	3	2	1	3	18.46±0.09
9	3	3	2	1	16.12±0.05
Level					
1	16.93	18.95	18.43	17.21	
2	17.15	16.73	16.22	17.86	
3	18.37	16.86	17.90	17.47	
Range	1.44	2.22	2.21	0.65	
Rank	3	1	2	4	

Changes in the appearance and texture of blanched cowpeas during frozen storage

Changes in appearance and microstructure could reflect the degree of browning and quality changes in blanched cowpeas during frozen storage (Guo et al. 2007). Changes in the appearance and microscopic structure of blanched cowpeas during frozen storage are shown in Figure 5. On day 0, cowpeas from the control group had intact cell structures, tightly packed and orderly. Those from the treatment group also had orderly and structured cells, with a fresh green surface, plump shapes, and no signs of browning, with little noticeable difference between the two groups. After 5 days of frozen storage, cowpeas from the control group remained intact with unchanged cell structures. Those from the treatment group exhibited tightly arranged, orderly cells with a more vibrant color than the control group. After 10 days of frozen storage, cowpea cells from the control group began to disperse, showing slight deformation. Those from the treatment group retained intact cell structure without deformation, and the color was more vibrant than those from the control group. After 20 days of frozen storage, the cell structure of cowpeas from the control group was severely damaged and deformed, with no visible intact cells. Those from the treatment group still exhibited some orderly cell arrangement, although more structured than in the control group, but with some disruptions and deformations. The cowpeas in the treatment group had yellow, shriveled epidermis, but their appearance was better than that of the control group. By day 30 of frozen storage, the cowpeas in the control group no longer exhibited any visible cell structure. However, the cowpeas in the treatment group showed collapsed and deformed cells. The cowpeas in both groups turned yellow, developed unpleasant odor upon thawing, and both groups substantially lost their edible value. In conclusion, blanching helped preserve the green color and cell morphology of the cowpeas in both groups for longer periods.

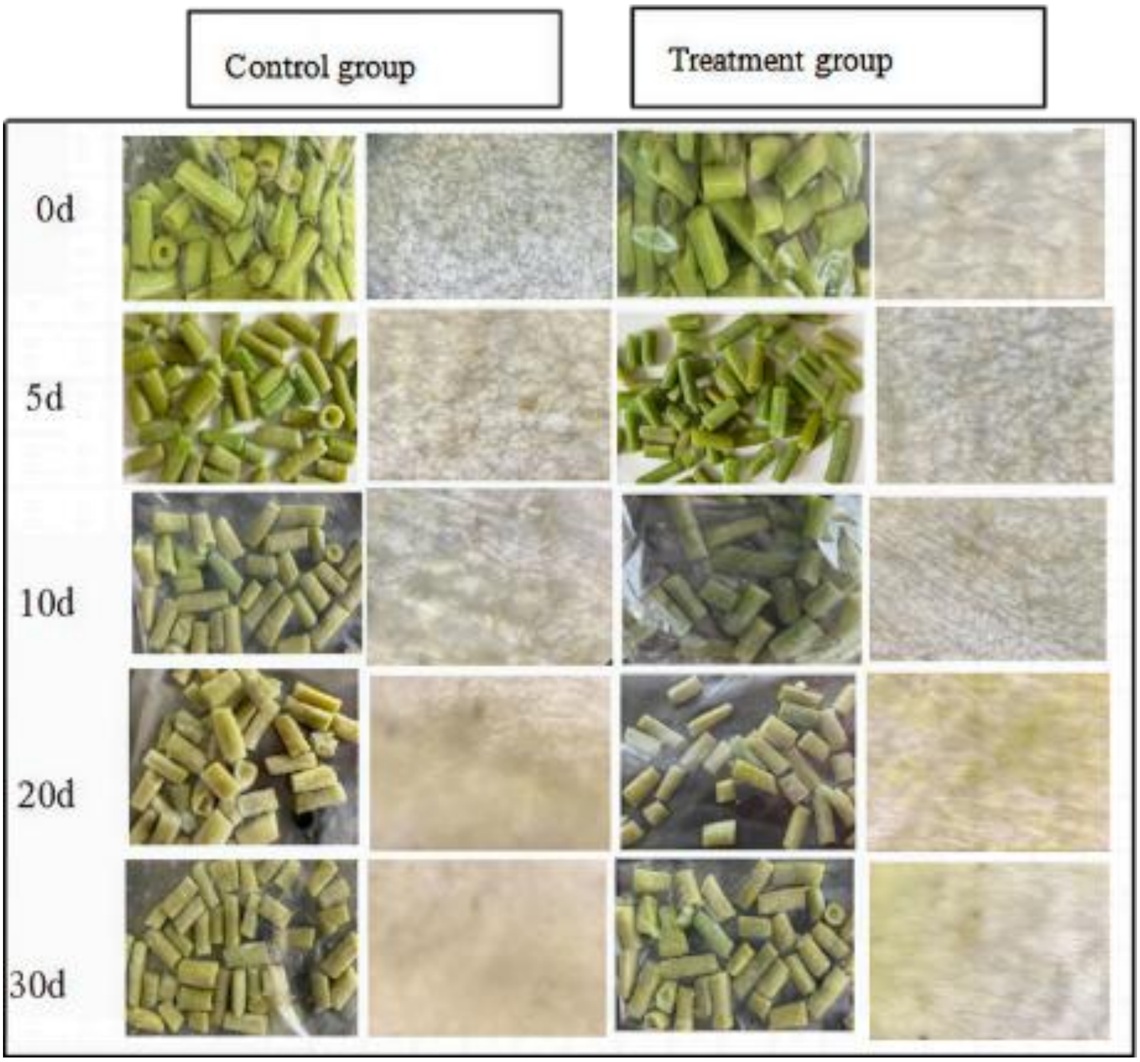

Figure 5. Effect of blanching with 0.09% baking soda and 1.5% soybean oil for 50 seconds, with a solid-to-liquid ratio of 1:10, on the appearance and microstructure of cowpea (10× magnification)

Changes in sensory quality

As shown in Table 2, for cowpeas to be considered marketable and commercially viable, their sensory score needed to exceed 6. When the sensory score was below 6, the cowpeas were considered to have lost their commercial value (Fig. 6). Over time, both the control and treatment groups showed a decreasing trend in appearance scores, corresponding to changes in phenotypic appearance. During the frozen storage period, the sensory score in the control group dropped below 6 after day 15, while the score in the treatment group only dropped below 6 after 30 days. In conclusion, the green preservation treatment helped the cowpeas maintain a higher sensory score, thereby extending their shelf life by 10 days.

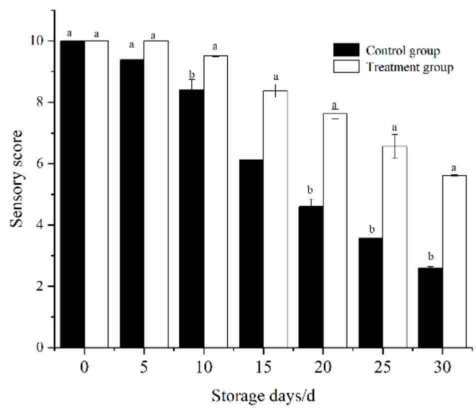

Figure 6. Effect of blanching with 0.09% baking soda and 1.5% soybean oil for 50 seconds, with a solid-to-liquid ratio of 1:10, on the sensory evaluation of cowpeas during frozen storage
Different lowercase letters indicate significant differences ($P < 0.05$)

Changes in the rate of weight loss during frozen storage

Changes in the weight loss rate of blanched cowpeas during frozen storage are shown in Figure 7. Both the control and treatment groups exhibited an increasing trend in the weight loss rate with increasing of frozen storage time. At the same frozen storage time, the control group had a significantly higher weight loss rate than the treatment group. After 20 days of frozen storage, the weight loss rate in the control group reached 3.4%, while that in the treatment group was 2.3%. After 30 days of frozen storage, the weight loss rate in the control group was 4.9%, while that in the treatment group was only 3.0%. These results indicate that blanching can slow moisture loss in cowpeas.

Changes in cowpea decay rate during frozen storage

Decay began after 15 days (4%) in the control group and after 20 days (less than 1%) in the treatment group (Fig. 8). Although both groups exhibited an increasing rate of decay during frozen storage, the control group always showed a greater rate of decay. After 30 days of frozen storage, the decay rate in the control group increased to 10%, while in the treatment group it was a constant 5%. These results suggest that blanching inhibited cowpea decay during storage, extending its shelf life by 20–25 days.

Changes in chlorophyll content during frozen storage

Changes in chlorophyll content in blanched cowpeas during frozen storage are shown in Figure 9. From day 15, chlorophyll content in the control group was significantly lower. With increasing frozen storage time, all cowpeas exhibited a decreasing trend in chlorophyll content, with a greater decrease in the control group. After 20 days of frozen storage, chlorophyll content in the control group decreased to 85.82% of the initial value, while in the treatment group, chlorophyll content decreased less, reaching 90.54%. After 25 days of frozen storage, the control group had 73.12% of the initial chlorophyll content (a 26.88% decrease), while the treatment group had 77.29% of the initial value (a 22.71% decrease). In conclusion, blanching can maintain higher chlorophyll levels and reduce its loss, slow down the rate of yellowing in cowpeas, and thus extend shelf life by approximately 20 days.

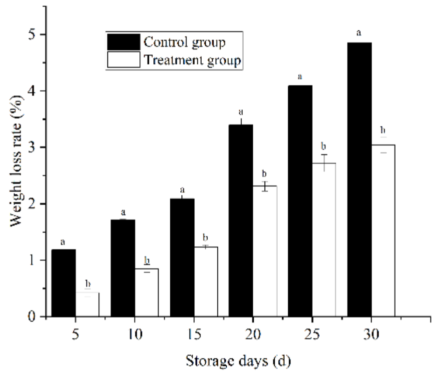

Figure 7. Effect of blanching on the rate of weight loss during frozen storage
Different lowercase letters indicate significant differences (P < 0.05)

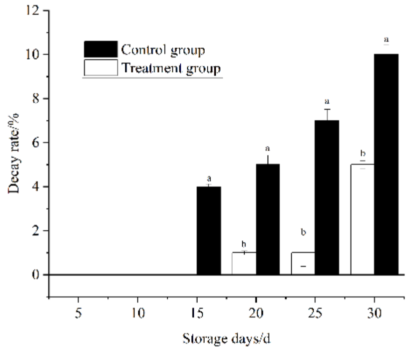

Figure 8. Effect of blanching on the decay rate during frozen storage
Different lowercase letters indicate significant differences (P < 0.05)

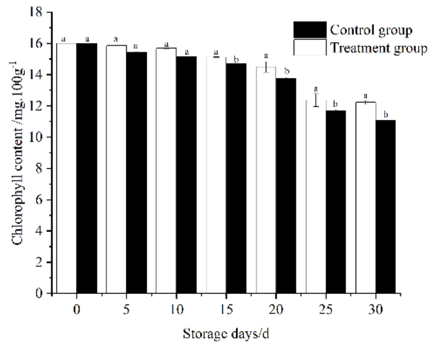

Figure 9. Effect of blanching on chlorophyll content during frozen storage
Different lowercase letters indicate significant differences (P < 0.05)

Changes in vitamin C content during frozen storage

Changes in vitamin C content during frozen storage are shown in Figure 10. During frozen storage, a decreasing trend in vitamin C content was observed in both control and treated cowpeas, with a significantly faster decline in the control group. However, the decline in vitamin C content in the treatment group was relatively slower. In conclusion, blanching effectively slowed the degradation of vitamin C in cowpeas, maintaining its content at a higher level and thereby extending the shelf life of cowpeas to approximately 20 days.

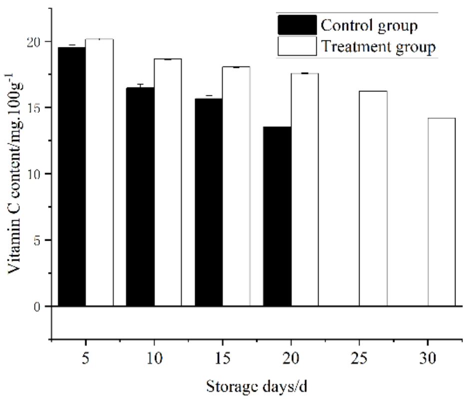

Figure 10. Effect of blanching on vitamin C content during frozen storage
Different lowercase letters indicate significant differences ($P < 0.05$)

A combination of chemical and physical factors influences the chlorophyll preservation and the overall quality of cowpeas. Chlorophyll, a photosynthetic pigment first identified by Pelletier and Caventou in 1817 (Davies 2004), plays a vital role in converting solar energy into chemical energy (Jubert & Bailey 2007). Although leaf color may vary among species due to the presence of other pigments (Humphrey 1980), the chlorophyll molecule itself has a structure consisting of a porphyrin ring coordinated to a central magnesium ion (Mg^{2+}) and a phytol tail (Ferruzzi & Blakeslee 2007). However, this structure is susceptible to degradation under the influence of factors such as temperature, light, oxygen, pH changes, and enzymatic activity. Degradation typically begins with the loss of the central Mg^{2+} ion, leading to the formation of pheophytin and a color change from intense green to olive-brown (Solymosi & Mysliwa-Kurdziel 2017; Kong et al. 2023).

Several strategies have been developed to counteract chlorophyll degradation. The alkaline properties of baking soda promote saponification of the ester groups in the chlorophyll molecule, leading to the formation of more stable alkaline chlorophyll salts (Gugouch & Elghorba 2024). Additionally, the presence of metal ions such as Cu^{2+} or Zn^{2+} can help preserve the green color by binding to the porphyrin ring, stabilizing the central magnesium ion and increasing resistance to acidity and heat, thus preventing color loss (Kidmose et al. 2002; Davies 2004; Ngamwonglumlert et al. 2017). Because chlorophyll is fat-soluble, the addition of soybean oil increases its release efficiency. However, this effect is concentration-dependent and optimal within a specific range (Bianchi et al. 2015). Furthermore, solution volume influences chlorophyll extraction and retention through its effect on mass transfer. A smaller volume creates a steeper concentration gradient, which favors higher extraction yields. Conversely, excessive volume reduces this gradient, decreasing efficiency and resulting in resource waste (Guo et al. 2007; Xie et al. 2013b).

In fruit and vegetable processing, blanching is an effective pretreatment method that controls enzymatic browning, microbial survival, improves marketability, and preserve sensory qualities (Dai et al. 2023; Zhang et al. 2024). However, this process requires careful optimization because excessive heat exposure can damage the chlorophyll structure, accelerating its degradation to pheophytin (Kong et al. 2023). Therefore, it is important to explore blanching in combination with additives such as metal salts. In this study, treatment with 0.09% baking soda, 1.5% soybean oil, a solid-to-liquid ratio of 1 : 10, and a blanching time of 50 seconds resulted in cowpea samples with higher chlorophyll content. This combined approach effectively delayed deterioration during frozen storage, reduced weight loss and decay, and minimized chlorophyll and vitamin C losses.

These findings are consistent with previous research. For example, the addition of Zn^{2+} ions during extraction creates a stable zinc–chlorophyll complex that helps preserve the color of products such as bread and syrup after storage. At the same time, Mg^{2+} contributes to improved stability (Bui et al. 2021).

Similarly, the addition of sodium chloride (NaCl) during extraction has been shown to significantly prolong the stability of the green color compared to the control (Li et al. 2022). These interrelated mechanisms and empirical results highlight the importance of optimizing multiple parameters, including blanching, metal ion addition, oil addition, and the solid-to-liquid ratio, for practical color preservation and overall quality in cowpeas.

CONCLUSION

Conditions favorable for frozen storage of cowpeas included blanching at 100 °C for 50 seconds, using a 1 : 10 ratio of cowpea to blanching mixture containing 0.09% baking soda and 1.5% soybean oil. After these blanching preconditions, the frozen storage period at −20 °C was extended to 20–25 days. These conditions inhibited the decline in chlorophyll and vitamin C content, reduced weight loss and decay rates, and preserved the excellent sensory properties of the cowpeas.

Author contribution statement

JS – A – Research concept and design, B – Collection and/or assembly of data
LY – C – Data analysis and interpretation, D – Writing the article
SO – A – Research concept and design, D – Writing the article
QZ – B – Collection and/or assembly of data, D – Writing the article
ZZ – B – Collection and/or assembly of data, E – Critical revision of the article
LJ – F – Final approval of the article

REFERENCES

Abu-Ghannam N., Crowley H. 2006. The effect of low temperature blanching on the texture of whole processed new potatoes. Journal of Food Engineering 74(3): 335–344. DOI: 10.1016/j.jfoodeng.2005.03.025.

An R.H., Zhou N., Wei W.W., Jia L.W., Wang D., Ren Z.Y. et al. 2024. Effect of film packaging on shelf-life quality of fresh-cut lettuce. Packaging Engineering 45(3): 107–116. DOI: 10.19554/j.cnki.1001-3563.2024.03.013. [in Chinese with English abstract]

Baardseth P. 1978. Quality changes of frozen vegetables. Food Chemistry 3(4): 271–282. DOI: 10.1016/0308-8146(78)90035-3.

Bianchi L.M., Duncan S.E., Webster J.B., Neilson A.P., O'Keefe S.F. 2015. Contribution of chlorophyll to photooxidation of soybean oil at specific visible wavelengths of light. Journal of Food Science 80(2): C252–C261. DOI: 10.1111/1750-3841.12751.

Bui T.K.L., Hoang V.H.D., Nguyen T.Q., Tran H.H., Nguyen M.T., Pham H.L., Hoang T.C. 2021. Optimization of chlorophyll extraction in *Centella asiatica* L. Journal of Jilin University (Engineering and Technology Edition) 40(7): 37–45. DOI: 10.17605/osf.io/z5ecr.

Clark R., van der Burgt X., Banks H., Feika A.M.B., Lewis G. 2011. A synopsis of *Pseudovigna* (Leguminosae: Papilionoideae) including a new species, *P. sulaensis*, from Sierra Leone. Kew Bulletin 66(4): 589–599. DOI: 10.1007/s12225-011-9314-8.

Dai H.M., Dong Y., Li Y., Zhi H.H. 2023. Effects of blanching, steaming and freezing treatments on the storage and sensory qualities of vegetable soybeans. Food Science and Technology 48(10): 55–62. DOI: 10.13684/j.cnki.spkj.2023.10.005. [in Chinese with English abstract]

Davies K.M. 2004. Plant pigments and their manipulation. Annual Plant Reviews 14. Blackwell Publishing, UK, 352 p. DOI: 10.1002/9781119312994.

Duan R.B., Huang Z.F., Chen X.Q., Cao X., Li J., Yan S.L. 2025. Development and irradiation preservation technology study on fresh wet noodles incorporating lotus rhizome residue. Journal of Food Measurement and Characterization 19(3): 2007–2018. DOI: 10.1007/s11694-025-03096-x.

Favell D.J. 1998. A comparison of the vitamin C content of fresh and frozen vegetables. Food Chemistry 62(1): 59–64. DOI: 10.1016/s0308-8146(97)00165-9.

Fernández-León M.F., Fernández-León A.M., Lozano M., Ayuso M.C., González-Gómez D. 2013. Different postharvest strategies to preserve broccoli quality during storage and shelf life: Controlled atmosphere and 1-MCP. Food Chemistry 138(1): 564–573. DOI: 10.1016/j.foodchem.2012.09.143.

Ferruzzi M.G., Blakeslee J. 2007. Digestion, absorption, and cancer preventative activity of dietary chlorophyll derivatives. Nutrition Research 27(1): 1–12. DOI: 10.1016/j.nutres.2006.12.003.

Fraeye I., Duvetter T., Doungla E., Van Loey A., Hendrickx M. 2010. Fine-tuning the properties of pectin–calcium gels by control of pectin fine structure, gel composition and environmental conditions. Trends in Food Science and Technology 21(5): 219–228. DOI: 10.1016/j.tifs.2010.02.001.

Giannakourou M.C., Taoukis P.S. 2003. Kinetic modelling of vitamin C loss in frozen green vegetables under variable storage conditions. Food Chemistry 83(1): 33–41. DOI: 10.1016/s0308-8146(03)00033-5.

Gugouch F., Elghorba M. 2024. The impact of the environment of use on the behavior of polychlorinated (vinyl chloride). Environmental Science and Pollution Research 31(39): 51806–51814. DOI: 10.1007/s11356-024-34662-3.

Guo W.Y., Du B., Cheng Y.F., Yang G.M. 2007. The impact and application of freeze process on fruit and vegetable. Food and Machinery 23(2): 118–121. DOI: 10.3969/j.issn.1003-5788.2007.02.035. [in Chinese with English abstract]

Han Y.H. 2023. The blunt enzyme effect of far infrared radiation heating and its effect on conformation of polyphenol oxidase. M.Sc. thesis, Henan University of Science and Technology, China, 48 p. DOI: 10.27115/d.cnki.glygc.2023.000753. [in Chinese with English abstract]

Han L.C., Wang Z.R., Wang Q., Zuo J.H., Zheng Y.Y. 2023. Research progress on postharvest preservation technologies of cowpea. Modern Food Science and Technology 39(6): 321–330. DOI: 10.13982/j.mfst.1673-9078.2023.6.0724. [in Chinese with English abstract]

Huang L.M. 2022. Analysis of oil components in heat-damaged soybeans and study on stability and adsorption removal of four pigments. M.Sc. thesis, Henan University of Technology, China, 103 p. DOI: 10.27791/d.cnki.ghegy.2022.000117. [in Chinese with English abstract]

Humphrey A.M. 1980. Chlorophyll. Food Chemistry 5(1): 57–67. DOI: 10.1016/0308-8146(80)90064-3.

Jubert C., Bailey G. 2007. Isolation of chlorophylls *a* and *b* from spinach by counter-current chromatography. Journal of Chromatography A 1140(1–2): 95–100. DOI: 10.1016/j.chroma.2006.11.063.

Kidmose U., Edelenbos M., Nørbæk R., Christensen L.P. 2002. Colour stability in vegetables. In: MacDougall D.B. (Ed.), Colour in food: Improving quality. Woodhead Publishing, UK, pp. 179–232. DOI: 10.1533/9781855736672.2.179.

Kong Q.Q., Zhang J.H., Zhong Y.G., Cheng Y. 2023. Effect of blanching combined with 1-MCP treatment on quality of fresh-cut celery during storage. Journal of Shanghai University (Natural Science Edition) 29(4): 590–601. DOI: 10.12066/j.issn.1007-2861.2522. [in Chinese with English abstract]

Krajewski K., Żabka A., Bernasińska J., Matczak K., Maszewski J. 2015. Immunolocalization of dually phosphorylated MAPKs in dividing root meristem cells of *Vicia faba*, *Pisum sativum*, *Lupinus luteus* and *Lycopersicon esculentum*. Plant Cell Reports 34(6): 905–917. DOI: 10.1007/s00299-015-1752-6.

Li H.X. 2025. Research on the application of chemical preservatives in fruit and vegetable preservation. China Food 2: 104–106. DOI: 10.3969/j.issn.1000-1085.2025.02.033. [in Chinese]

Li X., Wang W.L., Wang Y.M., Liu L.N., Xu Z.X., Cui W.J. 2018. Development of brittleness keeping technology of low salt pickles. Food and Nutrition in China 24(12): 23–27. DOI: 10.3969/j.issn.1006-9577.2018.12.005. [in Chinese with English abstract]

Li F., Zhou L., Cao J., Wang Z., Liao X., Zhang Y. 2022. Aggregation induced by the synergy of sodium chloride and high-pressure improves chlorophyll stability. Food Chemistry 366; 130577; 8 p. DOI: 10.1016/j.foodchem.2021.130577.

Li J.H., Liu H.R., He H., Wang C.F., Liu C.X., Zhong Y.G., Hu L.S., Qiao Y.J. 2025a. Research of controlled atmosphere preservation technology in maintaining quality of fruits and vegetables during postharvest storage. Acta Agriculturae Shanghai 41(1): 143–150. DOI: 10.15955/j.issn1000-3924.2025.01.20. [in Chinese with English abstract]

Li B.X., Liu Z.J., Sun Z.C., Sun Y.R., Tian Z.Y., Liu Y. et al. 2025b. Changes in the storage quality of tomatoes in antimicrobial chitosan packaging cartons under 1-MCP sustained release treatment. Modern Food Science and Technology 41(7): 189–198. DOI: 10.13982/j.mfst.1673-9078.2025.7.0664. [in Chinese with English abstract]

Liu W., Dong Q. 2015. Research status of crispness-keeping and preservation of pickled vegetables. China Brewing 34(1): 5–9. DOI: 10.11882/j.issn.0254-5071.2015.01.002. [in Chinese with English abstract]

Liu P., Liao Y.W., Zhu B., Yang Y., Lu Z., Yao F. et al. 2024. Synergistic effect of prochloraz and iminoctadine tris on preservation of *Citrus reticulata* cv. Kinokuni. Journal of Nuclear Agricultural Sciences 38(10): 1961–1967. DOI: 10.11869/j.issn.1000-8551.2024.10.1961. [in Chinese with English abstract]

Luo Y.W., Yao Z.W., Chen D.K., Yang S.Z., Dai L.F. 2006. Analysis of nutritional components and health benefits of cowpea. China Fruit and Vegetable 2: 40. DOI: 10.3969/j.issn.1008-1038.2006.02.035. [in Chinese]

Lyu J.L., Li L.P., Wang G.Z. 2023. Effects of hot water blanching on antioxidant activity and bioavailability of ethanol extracts from red pepper. China Condiment 48(10): 20–26. DOI: 10.3969/j.issn.1000-9973.2023.10.004. [in Chinese with English abstract]

Lípová L., Krchňák P., Komenda J., Ilík P. 2010. Heat-induced disassembly and degradation of chlorophyll-containing protein complexes in vivo. Biochimica et Biophysica Acta 1797(1): 63–70. DOI: 10.1016/j.bbabio.2009.08.001.

Mandalari G., Bennett R.N., Kirby A.R., Lo Curto R.B., Bisignano G., Waldron K.W., Faulds C.B. 2006. Enzymatic hydrolysis of flavonoids and pectic oligosaccharides from bergamot (*Citrus bergamia* Risso) peel. Journal of Agricultural and Food Chemistry 54(21): 8307–8313. DOI: 10.1021/jf0615799.

Mazzeo T., Paciulli M., Chiavaro E., Visconti A., Fogliano V., Ganino T., Pellegrini N. 2015. Impact of the industrial freezing process on selected vegetables – Part II. Colour and bioactive compounds. Food Research International 75: 89–97. DOI: 10.1016/j.foodres.2015.05.036.

Ngamwonglumlert L., Devahastin S., Chiewchan N. 2017. Natural colorants: Pigment stability and extraction yield enhancement via utilization of appropriate pretreatment and extraction methods. Critical Reviews in Food Science and Nutrition 57(15): 3243–3259. DOI: 10.1080/10408398.2015.1109498.

GB 5009.86-2016. National Food Safety Standard – Determination of Ascorbic Acid in Foods. National Health and Family Planning Commission of the People's Republic of China.

Okafor V.N., Omokpariola D.O., Enenche D.E. 2024. Determination of vitamin C in raw fruit and vegetable homogenates: Dietary exposure and health effects of excess intake in adults and children. Annals of the National Institute of Hygiene 75(1): 21–33. DOI: 10.32394/rpzh.2024.0294.

Simon C., Fort A., Sulpice R. 2024. Cryopreservation of vegetative thalli of *Ulva* species. Journal of Applied Phycology 36(5): 3011–3016. DOI: 10.1007/s10811-024-03300-3.

Solymosi K., Mysliwa-Kurdziel B. 2017. Chlorophylls and their derivatives used in food industry and medicine. Mini-Reviews in Medicinal Chemistry 17(13): 1194–1222. DOI: 10.2174/1389557516666161004161411.

Tang M. 2016. Study on storage of postharvest Chinese cabbage with humidcool and ozone. M.Sc. thesis, Zhongkai University of Agriculture and Engineering, China, 77 p. DOI: 10.27700/d.cnki.gzcny.2016.000003. [in Chinese with English abstract]

Wang X.H., Liu D.Y., Xiao L.Q., Li J.X., Wang J.D. 2016. The color protection and brittleness-keeping process of the bamboo shoots sauce. Food Science and Technology 41(9): 117–119. DOI: 10.13684/j.cnki.spkj.2016.09.023. [in Chinese with English abstract]

Wang X.L., Niu Y., Du G.F., Qi Z.Q., Yang Y., Liu Z.H. 2024. Comparative analysis and comprehensive evaluation of cowpea varieties in Hainan. China Cucurbits and Vegetables 37(9): 151–158. DOI: 10.16861/j.cnki.zggc.202423.0812. [in Chinese with English abstract]

Wangmene B., Bayang J.P., Bayang R., Ali M., Koubala B.B., Harouna M. 2024. Effects of bio-insecticide formulated from *M. charantia* leaves extract in association with gum Arabic/kaolinite composite on mortality of *Callosobruchus maculatus* and nutritional composition of cowpea (*Vigna unguilata*). Journal of Agriculture and Food Research 18; 101428; 9 p. DOI: 10.1016/j.jafr.2024.101428.

Wei L.J., Feng Y.Q., Wei M. 2024. Mathematical modeling of spontaneous modified atmosphere packaging of broccoli. Food Research and Development 45(15): 59–64. DOI: 10.12161/j.issn.1005-6521.2024.15.008. [in Chinese with English abstract]

Wu Z.C., Liu Y.H., Liu Z.F., Feng J.H. 2006. The main factors of effect quick-freeze vegetables character. Food and Fermentation Industries 32(8): 97–100. DOI: 10.13995/j.cnki.11-1802/ts.2006.08.025. [in Chinese with English abstract]

Xie W., Yan S.L., Li C.L., Wang Q.Z., Li J. 2013a. Effects of pectin methyl esterase activity on texture of lotus root at different harvest seasons. Journal of Changjiang Vegetables 18: 56–59. DOI: 10.3865/j.issn.1001-3547.2013.18.018. [in Chinese with English abstract]

Xie Y.Q., Chen H., Luo Y., Li Y., Huang L. 2013b. Ultrasonic assisted extraction process study of mango chlorophyll. Light Industry Science and Technology 9: 36–38. [in Chinese]

Xu C. 2024. Storage and preservation technology of fresh-cut purple cabbage and its effect on its quality and physiological characteristics. M.Sc. thesis, Jilin Agricultural University, China, 78 p. DOI: 10.27163/d.cnki.gjlnu.2024.001023. [in Chinese with English abstract]

Yan Y. 2015. Research of processing key technology of fresh-cut green peppers and snap beans. M.Sc. thesis, Northeast Agricultural University, China, 67 p. DOI: 10.7666/d.y2771908. [in Chinese with English abstract]

Zhang F.P. 2008. Analysis about the effect of different temperature on preservation of *Vigna sinensis* during postharvest storage. Food Research and Development 29(2): 146–148. DOI: 10.3969/j.issn.1005-6521.2008.02.047. [in Chinese with English abstract]

Zhang H.T. 2023. Overview of preservation technology in edible agricultural products. China Food Safety 20: 46–48. DOI: 10.16043/j.cnki.cfs.2023.20.009. [in Chinese with English abstract]

Zhang X.J., Liu C.Y., Yang L.N. 2015. Present research on determination of pectin content. Applied Chemical Industry 44(4): 729–731, 735. DOI: 10.16581/j.cnki.issn1671-3206.2015.04.005. [in Chinese with English abstract]

Zhang C.G., Wu Z.L., Peng X.H., Li T.Y.F., Zhang X., Li X.Y. 2017. Study on processing technology of snack food with kohlrabi pickled by air drying dehydration. China Condiment 42(9): 76–79, 84. DOI: 10.3969/j.issn.1000-9973.2017.09.018. [in Chinese with English abstract]

Zhang T, Yuan Y., Wang X., Song X.X., Cui S.W., Yin J.Y. 2023. A review on classification, nutritional benefits of pulses and the products development. Science and Technology of Food Industry 44(4): 428–437. DOI: 10.13386/j.issn1002-0306.2022020161. [in Chinese with English abstract]

Zhang L.L., Li X.W., Yang T. 2024. Blanching process optimization and nutritional quality analysis of quick-frozen mulberry leaf vegetables. Storage and Process 24(9): 80–86. DOI: 10.3969/j.issn.1009-6221.2024.09.010. [in Chinese with English abstract]

Zhao S.C., Zhu H.Y., Tang X., Wang D., Gao P., Chen B.Y. et al. 2025. Effects of electron beam irradiation on microbial load, physicochemical properties, sensory quality, stability of active components, and antioxidant activity of *Platycodon grandiflorum* (Jacq.) A. DC. Applied Radiation and Isotopes 216; 111450; 12 p. DOI: 10.1016/j.apradiso.2024.111450.