AgroLife Scientific Journal - Volume 12, Number 2, 2023
ISSN 2285-5718; ISSN CD-ROM 2285-5726; ISSN ONLINE 2286-0126; ISSN-L 2285-5718

RESEARCH ON BLANCHING PRETREATMENT AND FREEZING TECHNOLOGY EFFECT ON SELECTED VEGETABLES

Mihaela Cristina DRĂGHICI[1], Mihaela GEICU-CRISTEA[1], Elisabeta Elena POPA[1], Amalia Carmen MITELUȚ[1], Paul Alexandru POPESCU[1], Urszula TYLEWICZ[2], Marco Dalla ROSA[2], Mona Elena POPA[1]

[1]University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd, District 1, Bucharest, Romania
[2]Alma Mater Studiorum-University of Bologna, Piazza Goidanich 60, 47521, Cesena, Italy

Corresponding author email: elena.eli.tanase@gmail.com

Abstract

Vegetables present high nutritional content, being rich in vitamins, minerals, dietary fibres, organic acids and antioxidant compounds. However, fresh vegetables are generally harvested seasonally, being available in their fresh form for short periods of time during the year, and are also highly perishable. Therefore, the necessity of preserving them for a longer period of time has been addressed, freezing becoming the main technique used in this scope, due to its ability to maintain the initial quality of the product. The aim of the present study was to determine the properties of several fresh vegetables in different moments during processing for freezing preservation, namely initial moment (fresh form), after blanching pretreatment, after freezing/thawing process. The vegetables that were studied during this study were green peas, green beans, broccoli, asparagus, oyster mushrooms, Agaricus bisporus mushrooms and eggplants. As quality indicators, the following were determined: acidity, aw, colour, total polyphenolic content, antioxidant activity and ascorbic acid content (where applied). The results showed varied values for the monitored parameters. Generally, significant differences were observed during processing, with increasing and decreasing values of the tested parameters depending on the tested sample and applied treatment.

***Key words**: pretreatment, freezing processing, vegetables properties.*

INTRODUCTION

Vegetables are widely consumed, being recommended in any diet due to their high nutritional content, such as vitamins, minerals, organic acids, antioxidants and dietary fibres (Bassey et al., 2021). They have low fat content and also low caloric values, being beneficial to human health (Paciulli et al., 2015; Xin et al., 2015). There are a lot of studies that identified the fact that the components of fruit and vegetables could play a role in the prevention of different diseases, including diabetes, cancer, cardiovascular disease or vision related problems (Wu et al., 2020). For example, eggplants (*Solanum melongena*) are known for their high phenolic content, being one of the top ten vegetables in terms of oxygen radical absorbance capacity (Vallespir et al., 2019). Green peas (*Lathyrus oleraceus*) are rich in proteins and are preferred by consumers because they can be consumed in various ways, including fresh, canned or frozen states. They are beneficial in improving cardiovascular disease, lowering blood pressure and regulating gastrointestinal function (Zhang et al., 2021). Green beans (*Phaseolus vulgaris*) have high fiber and carbohydrate content while present low fat and energy values (Zhang et al., 2021). They also have a high content of ascorbic acid, minerals and proteins (Kasim & Kasim, 2015). Asparagus (*Asparagus officinalis*) presents both nutritional and medicinal value, being rich in nutrients such as proteins, carbohydrates, free amino acids, minerals, vitamins and dietary fibre (Truong et al., 2022). Broccoli (*Brassica oleracea*) is considered a superfood, being one of the most consumed within Brassica vegetables. It is a great source of fibres, proteins and minerals (Langston et al., 2023), having some health benefits related to its antioxidant, anticarcinogenic and antimutagenic properties (Mulțescu et al., 2020). Oyster mushrooms (*Pleurotus ostreatus*) have applicability both in food and pharma industry. They are considered beneficial for human health, thanks to their high content in proteins, polysaccharides, polyphenols, amino acids and having good antibacterial, antioxidant, antitumoral and anti-inflammatory potential (Zhao et al., 2024). *Agaricus bisporus* is one of the most produced and consumed mushrooms worldwide, being also important from food and pharmaceutic point of view. It presents great nutritional quality, being rich in proteins, fibres, essential amino acids and low in fatty substances (Agboola et al., 2023). However, the moisture content in vegetables is around 90%, fact that make them highly perishable, easy to damage by mechanical wounding during harvesting, transportation and storage, leading to great losses. Therefore, there is a constant need to preserve them as soon as possible after harvesting, and one of the easiest ways to do it is freezing.

Freezing is one of the most used preservation methods in food industry, being suitable for agricultural products preservation, increasing also their off-season availability (Schudel et al., 2021). This process can reduce microbial and enzyme activity and also chemical reactions in food, leading to an extension of their shelf life (Leng et al., 2023). However, sometimes reducing enzyme activity is not enough for vegetable preservation and additional pretreatment is needed. Blanching is recognized as an essential step before freezing in the case of various vegetables processing. It has as main purpose enzyme inactivation (by enzyme proteins denaturation), preventing this way possible reactions that can deteriorate the product's quality (Deylami et al., 2016). It also reduces the initial microbial load of products, extending this way their shelf life (Guo et al., 2021).

The aim of this study was the characterization of several vegetables (eggplant, green peas, green beans, asparagus, broccoli, oyster mushroom, *Agaricus bisporus* mushroom) in different moments of their processing for freezing preservation.

MATERIALS AND METHODS

Vegetables were acquired from local market in Bucharest, and processed in the same day. Samples were washed, the inedible parts were removed and then the samples were divided, blanched (in hot water) and frozen. The thawing of vegetables was performed in refrigeration conditions.

The indicator enzymes that are present in plant tissues are peroxidases, which can cause the oxidation of various compounds, such as ascorbic acid or phenolic compounds (Tadesse et al., 2023). Therefore, the inactivation of peroxidase was determined for all samples using the Guaiacol indicator, and blanching parameters (temperature/time) were established. Further, physical-chemical and nutritional analysis were performed on samples in different stages of the processing, namely in fresh form, after blanching and after freezing/thawing process. The analysis performed were total titratable acidity, ascorbic acid content, total polyphenolic content, antioxidant activity and colour, which are briefly described further.

Total titratable acidity was performed using a method according to STAS 5952-58. 20 g of product were mixed with distilled water in a 250 ml flask and heated at 80°C for 15 min. The sample was allowed to cool down at room temperature, brought to 250 ml, filtered and titrated with NaOH 0.1N in the presence of phenolphthalein as color indicator. The results were expressed as % total acidity.

Ascorbic acid content was determined spectrophotometrically. 10 g of sample were extracted in oxalic acid. The mixture was then filtered and the samples were prepared according to the method described by Stanciu et al. (2022). Sample absorbance was read at 500 nm and the results were expressed as mg ascorbic acid/100 g DM (dry matter).

Total polyphenolic content was determined using Folin-Ciocalteu method. 5 g of sample were mixed with 25 g of ethanol and incubated in the dark at room temperature for 48 h. The mixture was then filtered and prepared according to the method previously described by Popa et al. (2019). The absorbance of the sample was then read at 765 nm and the results were expressed as mg gallic acid equivalents (GAE)/100 g DM.

Antioxidant activity was determined by evaluating the effect of dipheny l-2- picrylhydrazyl (DPPH) on the tested samples. 5 g of sample were mixed with 25 g of ethanol and incubated in the dark at room temperature for 48 h. The mixture was then filtered and prepared according to the method previously described by

Stanciu et al. (2022). The absorbance of the sample was measured at 515 nm and the results were expressed as quercetin equivalents (QE)/100 g DM.

Colour determination was performed using a HunterLab Miniscan XE Plus equipment. Prior to sample reading, calibration against standard black and white plates was made. The colour of the samples was expressed in terms of L* (lightness), a* (greenness (-)/redness (+)) and b* (blueness(-)/yellowness(+)) parameters.

Statistical analysis was performed using SPSS software. Data are presented as average values ± standard deviations. One-way analysis of variance (ANOVA) was applied to determine the effects that blanching and freeze/thawing had on the tested samples, and Duncan's test was used to compare the differences between groups. The small letters within the tables show statistically significant differences ($p < 0.05$) between the mean values for samples subjected to different treatments.

RESULTS AND DISCUSSIONS

Peroxidase is the most thermal resistant enzyme and its complete inactivation could require longer treating time, fact that leads to nutrient loss (Zheng & Lu, 2011). Following peroxidase inactivation, the blanching conditions were established for each vegetable, as presented in Table 1.

Table 1. Blanching parameters established according to peroxidase inactivation

Sample	Blanching temperature (°C)	Blanching time (min)
Eggplant	95	5
Green peas	90	4
Green beans	95	9
Asparagus	95	10
Broccoli	90	3
Oyster mushroom	90	2
Agaricus bisporus mushroom	90	2

Total titratable acidity values obtained for the studied samples are presented in Table 2. Acidity registered significant ($p<0.05$) decreasing values during processing, the lowest values being registered for the thawed samples. This fact could be due to cellular juice loss during thawing, because of cell disruption during freezing by ice crystals formation.

Table 2. The values for total titratable acidity of the tested samples

Sample / Processing step	Fresh	Blanched	Freeze/Thawed
Eggplant	$3.92^a \pm 0.00$	$2.05^b \pm 0.00$	$0.81^c \pm 0.08$
Green peas	$6.77^a \pm 0.00$	$6.00^a \pm 0.50$	$3.18^b \pm 0.03$
Green beans	$3.15^a \pm 0.02$	$2.77^a \pm 0.15$	$1.78^b \pm 0.31$
Asparagus	$6.78^a \pm 0.53$	$2.97^b \pm 0.77$	$1.43^c \pm 0.06$
Broccoli	$7.28^a \pm 0.06$	$3.33^b \pm 0.03$	$2.66^c \pm 0.16$
Oyster mushroom	$3.04^a \pm 0.00$	$2.62^b \pm 0.00$	$1.17^c \pm 0.05$
Agaricus bisporus	$4.07^a \pm 0.00$	$2.79^b \pm 0.00$	$1.80^c \pm 0.00$

Different lowercase letters in rows indicate significant differences ($p < 0.05$) between the processed samples.

Table 3 shows the ascorbic acid content during processing of the studied vegetables. It is known that vitamin C is a heat labile component, therefore studies have reported vitamin C losses during blanching (Aadil et al., 2019). However, there are some studies that reported the fact that a good retention or no loss of vitamin C was observed in samples blanched by microwave (Punathil & Basak, 2016; Koutchma, 2023). After blanching, different samples presented a different behaviour, such as significant ($p<0.05$) ascorbic acid loss for asparagus, no modification for green peas and significantly higher ($p<0.05$) ascorbic acid content for green beans and broccoli. This differences in results could be attributed to variations of temperature and time of blanching, but also to the properties of each studied vegetable. Lee et al. (2018) also found vitamin C in high amounts in heat treated broccoli. Their study showed a 668.04 mg/kg ascorbic acid content in raw vegetable, and higher amounts in steamed (761.48 mg/kg) and microwaved (836.15 mg/kg) broccoli. The significant lower ($p<0.05$) values for ascorbic acid obtained for the thawed samples are in accordance with other research studies. For example, Zhang F. et al. (2021) determined a decrease in vitamin C content of blanched baby mustard thawed in refrigeration conditions. Similarly, Chen et al. (2022) also observed decreasing values of ascorbic acid following thawing process, fact that could be expected due to its solubility in water and also due to enzymatic or non-enzymatic oxidation reactions.

Table 3. Ascorbic acid content of the tested samples

Sample / Processing step	Fresh	Blanched	Freeze/Thawed
Eggplant	NA	NA	NA
Green peas	$60.49^{c} \pm 0.00$	$60.75^{b} \pm 0.00$	$64.92^{a} \pm 0.00$
Green beans	$174.75^{b} \pm 0.38$	$184.37^{a} \pm 0.00$	$150.58^{c} \pm 0.36$
Asparagus	$237.93^{a} \pm 0.36$	$222.13^{b} \pm 0.21$	$186.63^{c} \pm 0.21$
Broccoli	$177.68^{c} \pm 0.16$	$276.73^{a} \pm 5.44$	$239.26^{b} \pm 0.57$
Oyster mushroom	NA	NA	NA
Agaricus bisporus	NA	NA	NA

NA-not applied.

Different lowercase letters in rows indicate significant differences ($p < 0.05$) between the processed samples.

Polyphenolic content of the studied vegetables increased after blanching for eggplant, asparagus and broccoli samples (Table 4). Similar results were obtained by Bamidele et al. (2017), who determined the effect of blanching in hot water of six green leafy vegetables. It was found that a blanching temperature of 90°C for 5 minutes led to a significant increase ($p<0.05$) in total phenolic content and antioxidant activity in all tested vegetable samples. Further, the values of total polyphenolic content obtained for green peas, green beans, oyster mushroom and *Agaricus bisporus* mushroom decreased. Wen et al. (2010) also reported variation in polyphenolic content and antioxidant activity with increasing or decreasing values after blanching, depending on type of vegetables. Similarly, Ninfali and Bacchiocca (2003) determined total polyphenolic content and antioxidant activity in six fresh and frozen vegetables, namely broccoli, spinach, beet green, celery, onion and carrot. Four of them presented lower phenolic and antioxidant activity values compared to fresh products, while the other two had significantly higher values for these parameters.

Table 4. Total polyphenolic content of the tested samples

Sample / Processing step	Fresh	Blanched	Freeze/Thawed
Eggplant	$1228.77^{b} \pm 64.81$	$1732.11^{a} \pm 66.40$	$897.40^{c} \pm 133.44$
Green peas	$226.46^{a} \pm 6.34$	$179.53^{b} \pm 0.01$	$176.78^{b} \pm 14.45$
Green beans	$809.62^{a} \pm 128.77$	$746.93^{a} \pm 55.74$	$642.71^{a} \pm 5.32$
Asparagus	$1002.65^{b} \pm 47.84$	$1354.39^{a} \pm 55.76$	$1249.07^{a} \pm 61.34$
Broccoli	$1257.45^{a} \pm 92.61$	$1968.42^{a} \pm 929.35$	$1702.52^{a} \pm 152.85$
Oyster mushroom	$1304.59^{a} \pm 156.83$	$723.32^{b} \pm 5.45$	$517.38^{c} \pm 16.48$
Agaricus bisporus	$1246.52^{a} \pm 128.06$	$1177.68^{a} \pm 103.48$	$704.50^{b} \pm 70.62$

Different lowercase letters in rows indicate significant differences ($p < 0.05$) between the processed samples.

Antioxidant activity values varied between samples and processing steps (Table 5). Increased antioxidant activity was observed after blanching for all vegetable samples except mushrooms, which presented lower values for this parameter. Similar results were also found by Punathil and Basak (2016), when used microwave blanching on peppers. The antioxidant activity of the blanched samples increased, fact that could be explained by the generation of phenolic derivatives during blanching, with enhanced antioxidant activity. Aadil et al. (2019) also observed an increase of the antioxidant activity after juice blanching, most probably due to the retention of phenolic compounds. Antioxidant activity and total phenolic content were also proved to increase after blanching of samnamul (98°C for 30 s), but increasing blanching time showed rapid decrease of the values of these parameters (Kim et al., 2019). Thawing process led to significant smaller ($p<0.05$) values for antioxidant activity compared to fresh vegetables in case of eggplant, oyster mushroom and *Agaricus bisporus* mushroom. Similar results were obtained in a study performed by Stinco et al. (2013), where the antioxidant activities of microwave thawed orange juice samples registered smaller values compared to fresh juices. Green beans and broccoli showed insignificant changes during processing ($p > 0.05$). Broccoli and asparagus showed higher antioxidant activity in thawed samples compared to the fresh ones, results also obtained by Ninfali and Bacchiocca (2003) who observed that the antioxidant activity in frozen broccoli was conserved.

Table 5. Antioxidant activity of the tested samples

Sample / Processing step	Fresh	Blanched	Freeze/Thawed
Eggplant	$1230.16^{b} \pm 1.04$	$1960.60^{a} \pm 1.17$	$891.18^{c} \pm 103.88$
Green peas	$96.41^{b} \pm 3.16$	$183.34^{a} \pm 18.91$	$137.74^{ab} \pm 40.89$
Green beans	$1597.81^{a} \pm 66.25$	$1795.12^{a} \pm 485.34$	$817.76^{b} \pm 54.58$
Asparagus	$1212.45^{c} \pm 116.02$	$5753.45^{a} \pm 229.87$	$3630.48^{b} \pm 138.22$
Broccoli	$3350.63^{c} \pm 73.81$	$4890.56^{b} \pm 24.09$	$5405.58^{a} \pm 276.95$
Oyster mushroom	$3491.35^{a} \pm 469.65$	$1098.00^{b} \pm 1.00$	$927.55^{b} \pm 51.30$
Agaricus bisporus	$3232.39^{a} \pm 310.68$	$3133.41^{a} \pm 209.19$	$1694.95^{b} \pm 13.74$

Different lowercase letters in rows indicate significant differences ($p < 0.05$) between the processed samples.

Regarding colour determination (Tables 6-8), changes were observed during processing. L* values significantly decreased ($p<0.05$) during processing for eggplant, oyster mushroom and *Agaricus bisporus* mushroom, while for the other tested samples values remained similar. In respect to a* parameter, significant differences ($p<0.05$) were observed in case of eggplant which presented a negative value in fresh form (tendency to green colour), fact that could be attributed to the oxidation of the untreated sample. After blanching and thawing, samples registered positive values, which mean the colour slightly shifted towards red most probably due to enzymatic exposure (Priyadarshini et al., 2023). Green peas, green beans, broccoli and asparagus had negative values which are specific for green products, values that were not significantly different during processing. Regarding b* parameter, similar values were registered during processing for all vegetable samples. Briefly, significant ($p<0.05$) decreasing values were registered for eggplant and green peas, showing a decreasing yellowness intensity of these samples. Green beans presented similar b* values for fresh and blanched samples, showing that the treatment did not significantly affect the colour of the sample ($p>0.05$). However, higher values were observed for freeze/thawed sample. Significant changes ($p<0.05$) were observed for green beans, asparagus, broccoli, oyster mushroom and *Agaricus bisporus* samples, with increasing and decreasing values during processing, compared to the fresh samples.

Table 6. L* values for the studied samples

Sample / Processing step	Fresh	Blanched	Freeze/Thawed
Eggplant	$74.09^{a} \pm 0.24$	$47.64^{b} \pm 2.36$	$31.61^{c} \pm 0.58$
Green peas	$53.04^{b} \pm 0.15$	$56.03^{a} \pm 0.10$	$46.19^{c} \pm 0.82$
Green beans	$36.63^{b} \pm 0.28$	$39.00^{a} \pm 0.36$	$36.50^{b} \pm 0.67$
Asparagus	$42.95^{a} \pm 2.07$	$42.02^{a} \pm 0.34$	$40.12^{b} \pm 1.85$
Broccoli	$37.19^{b} \pm 0.51$	$31.10^{c} \pm 3.41$	$44.78^{a} \pm 3.86$
Oyster mushroom	$64.70^{a} \pm 1.41$	$60.87^{b} \pm 0.77$	$46.59^{c} \pm 0.77$
Agaricus bisporus	$76.66^{a} \pm 1.09$	$65.81^{b} \pm 0.94$	$36.69^{c} \pm 1.38$

Different lowercase letters in rows indicate significant differences ($p < 0.05$) between the processed samples.

Table 7. a* values for the studied samples

Sample / Processing step	Fresh	Blanched	Freeze/Thawed
Eggplant	-0.13[c] ± 0.43	7.23[a] ± 0.73	4.95[b] ± 0.17
Green peas	-10.23[a] ± 0.06	-14.02[c] ± 0.16	-10.59[b] ± 0.27
Green beans	-8.39[c] ± 0.04	-5.88[b] ± 0.26	-5.07[a] ± 0.49
Asparagus	-6.36[a] ± 0.46	-7.89[b] ± 0.41	-6.54[a] ± 0.79
Broccoli	-7.13[a] ± 0.15	-13.79[c] ± 0.59	-10.53[b] ± 0.41
Oyster mushroom	1.40[c] ± 0.19	2.06[b] ± 0.07	2.90[a] ± 0.11
Agaricus bisporus	2.49[b] ± 0.10	2.79[b] ± 0.19	6.43[a] ± 0.57

Different lowercase letters in rows indicate significant differences ($p < 0.05$) between the processed samples.

Table 8. b* values for the studied samples

Sample / Processing step	Fresh	Blanched	Freeze/Thawed
Eggplant	33.99[a] ± 0.89	22.87[b] ± 0.43	18.82[c] ± 0.48
Green peas	38.05[a] ± 0.13	37.53[b] ± 0.29	33.27[c] ± 0.53
Green beans	19.67[b] ± 0.24	19.60[b] ± 0.39	22.27[a] ± 1.12
Asparagus	32.47[c] ± 1.12	36.58[a] ± 1.03	34.56[b] ± 0.77
Broccoli	16.67[c] ± 1.00	26.35[b] ± 3.07	32.32[a] ± 1.15
Oyster mushroom	20.52[b] ± 0.24	19.54[c] ± 0.31	21.20[a] ± 1.10
Agaricus bisporus	14.30[c] ± 0.35	19.25[a] ± 0.50	17.91[b] ± 0.82

Different lowercase letters in rows indicate significant differences ($p < 0.05$) between the processed samples.

CONCLUSIONS

Blanching is mainly used for enzymatic inactivation and also colour preservation of vegetables and is often used as a necessary step before applying the preservation processes, such as drying, canning of freezing. The aim of our study was to characterize seven vegetables in different moments during processing. According to the results obtained, there are some variations in nutritional characteristics, which can be attributed to various factors, including sample properties, type and processing parameters (time and temperature). Generally, no major negative impact was observed after sample processing, vegetables retaining the majority of their ascorbic acid and polyphenolic content, as well as antioxidant activity. Also, the applied treatments led to significant changes in the colour of the studied samples, depending on the nature of the sample and the applied treatment.

ACKNOWLEDGEMENTS

This work was supported by a grant of the University of Agronomic Sciences and Veterinary Medicine of Bucharest, project number 2022-0004, Contract number 1063/15.06.2022, acronym PROVEG, within IPC 2021.

REFERENCES

Aadil, R. M., Roobab, U., Sahar, A., Rahman, U., & Khalil, A. A. (2019). 7 - Functionality of Bioactive Nutrients in Beverages, published in *Nutrients in Beverages*, Vol. 12: The Science of Beverages, 237-276.

Agboola, O. O., Sithole, S. C., Mugivhisa, L. L., Amoo, S. O., & Olowoyo, J. O. (2023). Growth, nutritional and antioxidant properties of *Agaricus bisporus* (crimini and white) mushrooms harvested from soils collected around mining areas in South Africa. *Measurement: Food*, *9*, 100078.

Bamidele, O. P., Fasogbon, M. B., Adebowale, O. J., & Adeyanju, A. A. (2017). Effect of Blanching Time on Total Phenolic, Antioxidant Activities and Mineral Content of Selected Green Leafy Vegetables. *Current Journal of Applied Science and Technology*, *24*(4), 1-8.

Bassey, E. J., Cheng, J. H., & Sun, D. W. (2021). Novel nonthermal and thermal pretreatments for enhancing drying performance and improving quality of fruits and vegetables, *Trends in Food Science & Technology*, *112*, 137-148.

Chen, B., Zhang, M., Wang, Y., Devahastin, S., & Yu, D. (2022). Comparative study of conventional and novel combined modes of microwave- and infrared-assisted thawing on quality of frozen green pepper, carrot and cantaloupe. *LWT - Food Science and Technology*, *154*, 112842.

Deylami, M. Z., Rahman, R. A., Tan, C. P., Bakar, J., & Olusegun, L. (2016). Effect of blanching on enzyme activity, color changes, anthocyanin stability and extractability of mangosteen pericarp: A kinetic study. *Journal of Food Engineering*, *178*, 12-19.

Guo, Y., Wu, B., Guo X., Liu, D., Wu, P., Ma, H., & Pan, Z. (2021). Ultrasonication and thermosonication blanching treatments of carrot at varying frequencies: Effects on peroxidase inactivation mechanisms and quality characterization evaluation. *Food Chemistry*, *343*, 128524.

Kasim, R., & Kasim, M. U. (2015). Biochemical changes and color properties of fresh-cut green bean (*Phaseolus vulgaris* L. cv.*gina*) treated with calcium chloride during storage. *Food Science and Technology*, *35*(2), 266-272.

Kim, A. N., Lee, K. Y., Rahman, M. S., Kim, H. J., Chun, J., Heo, H. J., Kerr, W. L., & Choi, S. G. (2019). Effect of water blanching on phenolic compounds, antioxidant activities, enzyme inactivation, microbial reduction, and surface structure of samnamul (*Aruncus dioicus* var *kamtschaticus*). *International Journal of Food Science & Technology*, *55*(4), 1754-1762.

Koutchma, T. (2023). Chapter 1 - Basic principles and mechanisms of electromagnetic heating technologies for food processing operations, in *Microwave and Radio Frequency Heating in Food and Beverages*, Academic Press, 3-27.

Langston, F., Redha, A. A., Nash, G. R., Bows, J. R., Torquati, L., Gidley, M. J., & Cozzolino, D. (2023). Qualitative analysis of broccoli (*Brassica oleracea* var. *italica*) glucosinolates: Investigating the use of mid-infrared spectroscopy combined with chemometrics. *Journal of Food Composition and Analysis*, *123*, 105532.

Lee, S., Choi, Y., Jeong, H. S., Lee, J., & Sung, J. (2018). Effect of different cooking methods on the content of vitamins and true retention in selected vegetable. *Food Science and Biotechnology*, *27*(2), 333-342.

Leng, D., Zhang, H., Tian, C., Li, P., Kong, F., & Zhan, B. (2023). Static magnetic field assisted freezing of four kinds of fruits and vegetables: Micro and macro effects. *International Journal of Refrigeration*, *146*, 118-125.

Mulțescu, M., Zachia, M., Belc, N., Burnichi, F., & Israel-Roming, F. (2020). Antioxidants in fresh and cooked broccoli (*Brassica oleracea* var. *Avenger*) and cauliflower (*Brassica oleracea* var. *Alphina* F1). *Scientific Bulletin. Series F. Biotechnologies*, *XXIV*(1), 107-113.

Ninfali, P., & Bacchiocca, M. (2003). Polyphenols and Antioxidant Capacity of Vegetables under Fresh and Frozen Conditions. *Journal of Agricultural and Food Chemistry*, *51*, 2222-2226.

Paciulli, M., Ganino, T., Pellegrini, N., Rinaldi, M., Zaupa, M., Fabbri, A., & Chiavaro, E. (2015). Impact of the industrial freezing process on selected vegetables - Part I. Structure, texture and antioxidant capacity. *Food Research International*, *74*, 329-337.

Popa, M. E., Stan, A., Popa, V., Tanase, E. E., Mitelut, A. C., & Badulescu, L. (2019). Postharvest quality changes of organic strawberry Regina cultivar during controlled atmosphere storage. *Quality Assurance and safety of crops & Foods*, *11*(7), 631-636.

Priyadarshini, A., Rayaguru, K., Biswal, A. K., Panda, P. K., Lenka, C., & Misra, P. K. (2023). Impact of conventional and ohmic blanching on color, phytochemical, structural, and sensory properties of mango (*Mangifera indica* L.) cubes: A comparative analysis. *Food Chemistry Advances*, *2*, 100308.

Punathil, L., & Basak, T. (2016). Microwave Processing of Frozen and Packaged Food Materials: Experimental. *Reference Module in Food Science*, Elsevier, ISBN 9780081005965, https://doi.org/10.1016/B978-0-08-100596-5.21009-3.

Schudel, S., Prawiranto, K., & Defraeye, T. (2021). Comparison of freezing and convective dehydrofreezing of vegetables for reducing cell damage. *Journal of Food Engineering*, *293*, 110376.

Stanciu, I., Dima, R., Popa, E. E., & Popa, M. E. (2022). Nutritional characterization of organic seabuckthorn pomace. *Scientific Papers. Series B, Horticulture*, *LXVI*(1), 913-918.

Stinco, C. M., Fernández-Vázquez, R., Heredia, F. J., Meléndez-Martínez, A. J., & Vicario, I. M. (2013). Bioaccessibility, antioxidant activity and colour of carotenoids in ultrafrozen orange juices: Influence of thawing conditions. *LWT - Food Science and Technology*, *53*(2), 458-463.

Tadesse, A. Y., Mohammed, H. H., & Andersa, K. N. (2023). Proximate composition and selected phytochemical component of Dawrach (*Raphanus raphanistrum* L.) as affected by blanching temperature. *Heliyon*, *9*, e19240.

Truong, T. Q., Nguyen, T. T., Cho, J. Y., Park, Y. J., Choi, J. H., Koo, S. Y., Kim, H. Y., Byun, H. G., & Kim, S. M. (2022). Effect of processing treatments on the phytochemical composition of asparagus (*Asparagus officinalis* L.) juice. *LWT - Food Science and Technology*, *169*, 113948.

Vallespir, F., Rodriguez, O., Eim, V. S., Rossello, C., & Simal, S. (2019). Effects of freezing treatments before convective drying on quality parameters: Vegetables with different microstructures. *Journal of Food Engineering*, *249*, 15-24.

Wen, T. N., Prasad, K. N., Yang, B., & Ismail, A. (2010). Bioactive substance contents and antioxidant capacity of raw and blanched vegetables. *Innovative Food Science & Emerging Technologies*, *11*(3), 464-469.

Wu, X., Wang, C., & Guo, Y. (2020). Effects of the high-pulsed electric field pretreatment on the mechanical properties of fruits and vegetables. Journal of Food Engineering, *274*, 109837.

Xin, Y., Zhang, M., Xu, B., Adhikari, B., & Sun, J. (2015). Research trends in selected blanching pretreatments and quick freezing technologies as applied in fruits and vegetables: A review. *International Journal of Refrigeration*, *57*, 11-25.

Zhang, C., Hu, C., Sun, Y., Zhang, X., Wang, Y., Fu, H., Chen, X., & Wang, Y. (2021). Blanching effects of radio frequency heating on enzyme inactivation, physiochemical properties of green peas (*Pisum sativum* L.) and the underlying mechanism in relation to cellular microstructure. *Food Chemistry*, *345*, 128756.

Zhang, F., Lin, P. X., Xia, P. X., Di, H. M., Zhang, J. Q., Huang, Z. S. Y., Li, H. X., & Sun, B. (2021). The effect of different thawing methods on the health-promoting compounds and antioxidant capacity in frozen baby mustard. *RSC Advances*, *11*(7), 9856-9864.

Zhang, X., Yi, W., Liu, G., Kang, N., Ma, L., & Yang, G. (2021). Colour and chlorophyll level modelling in vacuum-precooled green beans during storage. *Journal of Food Engineering*, *301*, 110523.

Zhao, Q., Liu, X., Cui, L., & Ma, C. (2024). Extraction and bioactivities of the chemical composition from *Pleurotus ostreatus*: a review. *Journal of Future Foods*, *4*(2), 111-118.

Zheng, H., & Lu, H. (2011). Effect of microwave pretreatment on the kinetics of ascorbic acid degradation and peroxidase inactivation in different parts of green asparagus (*Asparagus officinalis* L.) during water blanching. *Food Chemistry*, *128*, 1087-1093.