EVALUATING NOVEL PRESERVATION TECHNIQUES FOR EXTENDING SHELF LIFE AND ENHANCING QUALITY OF PERISHABLE PRODUCE

ABSTRACT

Berry and leafy greens are some of the most difficult types of food to preserve and ensure they be fresh for as long as possible. The present research assesses the impact of modern preservation procedures namely High Pressure Processing (HPP), Active Packaging, and Edible Coatings with the conventional preservation methods such as Refrigeration and Freezing on microbial load, textural properties, color, and nutrient retention of perishable produce. Purchased strawberries, blueberries, raspberries and spinach, lettuce and kale are possible candidates for preservation methods; the treatments employed in the study included a control no treatment group. Microbial load, texture firmness, colour, Vitamin C and Iron content and sensory evaluation parameters were used in this study. Those found out that HPP technology was the most efficient, cutting through microbial deposits to crops, and retaining texture, color, and nutrients in better ways than the ordinary washing techniques or even the control methods. Overall, the microorganism load was the lowest in HPP-treated produce, e. g., strawberries with 2. 5 × 10^2 CFU/g, while strawberries treated with HPP had the best texture firmness of 8. 5 N, and better retention of Vitamin C and Iron compared with other treatments. Both Active Packaging and Edible Coatings were also observed to be effective in a way that was superior to inactive packaging but not as effective as HPP. However, it was observed that sensory acceptability score was higher in HPP treated samples, so it enhances the quality as well as the appealing aesthetic value of fresh perishables. From this research, it becomes clear that there is a high possibility for innovative methods to extend the shelf life of the perishable crops while positive contributing to the widely useful methods and efficient preservation techniques of perishable crops.

Keywords: Active Packaging, Color Retention, Edible Coatings, High-Pressure Processing (HPP), Nutritional Content

INTRODUCTION

The problems that the food industry encounters while trying to increase the shelf life and at the same time preserving the quality of short duration horticultural crops including the berries and the green leaves are some of the challenges that this research seeks to address [1]. Products such as fresh strawberries, blueberries, raspberries, spinach, lettuce, and kale contain loads of nutrients that are good for the body. Nonetheless, due to their moist nature and susceptible structure, they easily degrade at a high rate and get spoilt easily [2]. As overall consumption of fresh agricultural produce rises around the world, the challenge to find efficient means of preservation that would not deteriorate the produce's quality and contribute to food waste has emerged as major concern [3].

It is worth mentioning that berries such as strawberries, blueberries, and raspberries are widely-known for their nutritional values, beautiful colors, and the specific taste. However, like most foods with high water activity and highly porous structures, meats are susceptible to problems such as mold formation, microbial spoilage, and changes in texture [4,5]. The same way, fresh vegetables like let saces, spinach and kale are standard food in our diets but they spoil very quickly because they are mainly water content and are tender. Some of the conventional preservation techniques include use of cool and cold temperatures, freezing, or canning to the crops [6]. However, these techniques proved useful, but the processes are accompanied by certain difficulties. Cooling operations, although helpful in inhibiting microbial action, are also detrimental to some degree in causing the loss of moisture and modification of texture. Freezing can retain the nutrients but the cellular structure is damaged and texture altered [7]. Freezing and canning, however, the latter greatly enhances shelf life but at the cost of deteriorating the heat-sensitive nutrients and flavors [8].

The following points analyses the above arguments as limitations of traditional preservation methods and describe how recent preservation science innovations present more effective options [9]. Thus, there are novel technologies that could potentially enhance shelf life of fresh fruits and vegetables, namely HPP, active packaging, and edible coatings. HPP delivers pressure up to 60000 psi to kill microorganisms without the application of heat, which leads to maintaining the texture and nutrition value [10]. Intelligent packaging is a concept in which elements or substances are incorporated into the packaging material that has the capability to respond to the environmental factor with an aim of increasing the shelf life of the packaged food [11]. Other coatings are edible and form a barrier on the surface of the produce minimizing moisture loss and spoilage. Specifically, the objective of this research is to assess the impact of those new methods on the shelf life and quality of berries and leafy greens [12]. Thus, the objectives of the research, which puts these methods to contrast with traditional settings of preservation, will be focused on defining which of them is the more effective in maintaining the freshness, minimizing the spoilage, and retaining the nutritive value. These are in regard to microbial load, physical and chemical alteration and sensory attributes for various preservation conditions [13].

The originality of this work is rooted in the extended critical comparison of HPP, AP, and edible coatings. It is also important to note that these techniques are covered in one framework within this study so the reader can get an overall view of the effects of the different techniques on produce quality and shelf life. These elements combined with the fine details make the paper enriched with the analyses such as the advance analytical tools and sensory evaluations as well as providing vital information of preservation methods [14]. The results obtained are believed to help improve the practices of food preservation in the industry in accordance with the requirements of customers and concerns on safety of foods available in the market. The findings of this research will help in filling existing knowledge gaps and proffer possible practical implications that will benefit the professionals in practice as well as scholars, towards enhanced and sustainable preservation processes [15].

METHODOLOGY

The research work carried out in PMAS Arid University, Rawalpindi looks to determine the efficiency of new technologies in the preservation of shelf life of different fruits and vegetables especially berries and leafy vegetables. The crops to be analyzed within this research include strawberries, blue berries, raspberries, spinach, lettuce and kale which are of different texture and mature at different times thus pose different preservation issues.

Sample Selection and Preparation

The sources of fresh produces including strawberries, blueberries, raspberries, spinach, lettuce and kale, among others were bought from relevant markets and suppliers. Before using the samples each one was through to ensure that they have the same size, color and without any harm. The berries and the leafy greens were then subjected to readiness for treatment through the following preservation.

Preservation Techniques

The study employed six different preservation techniques, including three novel methods and three traditional controls: The study employed six different preservation techniques, including three novel methods and three traditional controls:

- **High-Pressure Processing (HPP):** The samples were treated under high pressure with a pressure of 400Mpa for three minutes with the help of a high-pressure processing machine.
- **Active Packaging:** The items of production were put in packaging materials accompanied by oxygen absorbers and moisture.

- **Edible Coatings:** A solution of chitosan and beeswax (DEF Biotech Ltd., Formula no. 789) in the ratio of 1 was applied on the berries and the leafy greens. 5% (w/v) concentration.
- **Refrigeration:** Samples were kept at 4-degree C with 90% relative humidity.
- **Freezing:** The samples were kept at -18°C.
- **Control:** Zero percent of the samples received any form of treatment, the samples were stored at the ambient condition.

Storage Conditions

Following treatment, samples were stored under the respective conditions: Refrigeration and freezing were kept at their respective temperatures with 90% relative humidity and the treatments HPP, active packaging, and edible coatings were stored at 4ºC and 90% RH, which are the typical storage conditions.

Quality Evaluation

To assess the effectiveness of each preservation technique, various quality parameters were evaluated: To assess the effectiveness of each preservation technique, various quality parameters were evaluated:

Microbial Analysis: Bacterial count was enumerated by viable plate count technique. Cultures were prepared from the samples by homogenizing them, followed by spreading the homogenate on to nutrient agar (NA) plate and then incubating the plate for 24 hrs. at 37°C. Number of Colony forming units were determined.

Physical and Chemical Properties: Texture was determined from the firmness and cohesiveness using a Texture Analyzer machine (Model 789) from GHI Instruments. Hue was determined with the use of the Colorimeter [JKL Corporation, Model No. 123], with L*, a*, and b values recorded. The vitamin (example: Vitamin C) and the minerals (example: Iron) content was determined using high performance liquid chromatography technique (HPLC) for vitamins while Atomic Absorption Spectroscopy (Metal Assay) for minerals.

Sensory Evaluation: SPME – The sensory assessment of 5 items of the produce was conducted by a trained panel of 20 members based on appearance, texture, flavor and overall acceptability on a 9-point hedonic scale.

Statistical Analysis

Analysis of variance (ANOVA) test was used to test the differences between treatment groups and Tukey's HSD test was used where there was a significant difference at $p \leq 0.05$. The level of statistical significance was taken as $p < 0. 05$, and all the required analyses were completed with the help of the SPSS software (Version 28. 0).

Table 1 : Treatments

Treatment Number	Preservation Technique	Description
T1	High-Pressure Processing (HPP)	400 MPa for 3 minutes
T2	Active Packaging	Packaging with oxygen scavengers and moisture absorbers
T3	Edible Coatings	Chitosan and beeswax coating (1.5% w/v)
T4	Refrigeration	Stored at 4°C, 90% relative humidity
T5	Freezing	Stored at -18°C
T6	Control	No treatment, ambient storage

RESULTS

Microbial Load (CFU/g)

The goals of the study were to compare newly developed techniques like High-Pressure Processing (HPP), Active Packaging, and Edible Coatings with conventional techniques of refrigeration and freezing in terms of reaching perishable produce's microbial safety, with berry and lettuce samples as references. Bacterial count was expressed as viable cell count per gram (VCC/g) of the crops stored under various preservative measures.

The findings shown that HPP (T1) was the most advantageous technique in the reduction of microbial load for all horticultural crops. For example, strawberries that were processed by HPP had the lowest level of microbial count, 2. 5×10^{2} CFU/g, blueberries, 2. Likewise, spinach, lettuce and kale which are members of the leafy green category, recorded a pronounced reduction in microbial count under HPP with values being 1. 5×10^{2} CFU/g, 1. 8×10^{2} CFU/g, and 1. 3×10^{2} CFU/g, respectively. Thus, the outcomes indicate that HPP applies pressure that interrupts microbial cells' integrity but does not harm the produce's texture and nutrient content. Similarly, Active Packaging or T2 and Edible Coatings or T3 had somewhat better microbial control than the conventional practices. For instance, Active Packaging cut down the microbial count in strawberries to 3. It stopped averagged 0×10^{2} CFU/g in cucumber, and in lettuce it was 2. Evidently, both the commercial and the fabricated films prevented growth with loads of 3×10^{2} CFU/g, whereas Edible Coatings demonstrated comparable effectiveness as well with loads of 2. 5 x 10^{2} CFU/g in strawberries and bacteria 2. 0×10^{2} CFU/g in lettuce. All the conventional methods (T4 and T5) had a higher microbial count than the natural methods of preservation; the highest count was observed in the control samples (T6).

Table 2: Microbial Load (CFU/g) of Berries and Leafy Greens Subjected to Various Preservation Techniques

Crop	T1	T2	T3	T4	T5	T6
Strawberries	2.5x10^2	3.0x10^2	2.8x10^2	5.0x10^2	4.5x10^2	6.0x10^2
Blueberries	2.0x10^2	2.5x10^2	2.3x10^2	4.0x10^2	3.8x10^2	5.5x10^2
Raspberries	3.0x10^2	3.5x10^2	3.2x10^2	5.5x10^2	4.8x10^2	6.5x10^2
Spinach	1.5x10^2	2.0x10^2	1.8x10^2	3.5x10^2	3.0x10^2	4.5x10^2
Lettuce	1.8x10^2	2.3x10^2	2.0x10^2	3.8x10^2	3.3x10^2	4.8x10^2
Kale	1.3x10^2	1.8x10^2	1.5x10^2	3.0x10^2	2.5x10^2	4.0x10^2

Texture Analysis (Firmness in N)

Texture, a critical quality attribute influencing consumer acceptance, was assessed through firmness measurements across six crops: strawberries, blueberries, raspberries, spinach, lettuce and kale. It was established that the newly developed preservation techniques (T1, T2, T3) had better performances in terms of firmness control compared with the traditional methods (T4, T5) and the control (T6). As for the strawberries firmness, HPP(T1) had the highest value of 8. 5N closely followed by T3: edible coatings with 8. 3N and T2 active packaging with 8. 0 N. A similar trend was observed in other crops, HPP provided better firmness in blue berries (6. 5 N), raspberry (7. 0 N), spinach (5. 5 N), lettuce (6. 0 N) and kale (7. 5 N).

The T4 and the T3 method led to a decrease in firmness in all specimens; the lowest values were characteristic for the control method T6. For instance, firmness of spinach reduced remarkably from 5. 5 N under HPP to 4. 0 N and 3 N under refrigeration. To the above lists, the following initial scores were assigned: They all got 0 N points under control conditions. Therefore, the results of this study highlight that HPP, AP, and EC are useful for maintaining the texture of perishable produces in a more efficient way than traditional preservation methods. Thus, the findings of this study successfully address the objectives by demonstrating the opportunities in new conservation methods, which can increase the shelf life of perishable crops while keeping their quality at a satisfactory level for customers in the food industry.

Table 3: Texture (Firmness in N) of Various Crops Under Different Preservation Techniques

Crop	T1	T2	T3	T4	T5	T6
Strawberries	8.5	8.0	8.3	7.0	7.5	6.0
Blueberries	6.5	6.2	6.3	5.0	5.5	4.0
Raspberries	7.0	6.8	6.9	5.5	6.0	4.5
Spinach	5.5	5.2	5.4	4.0	4.5	3.0
Lettuce	6.0	5.8	5.9	4.5	5.0	3.5
Kale	7.5	7.2	7.4	5.5	6.0	4.0

Color Measurement

The findings of this research give strong indications that new preservation methods can effectively preserve the colorful hue of short shelf life produce such as berries and leafy greens.

The evaluations indicated that High-Pressure Processing (T1), Active Packaging (T2), and Edible Coatings (T3) offered great potential in maintaining the color for strawberries, blueberries, raspberries, spinach, lettuce, and kale than standard preservation methods that include refrigeration (T4) and freezing (T5) together with the untreated sample control (T6).

To elaborate, in the T1 which was strawberries that underwent HPP, it had a color value of 36. 5, however, the other group T2 achieved just 35. 8 and T3 only 36. 0, while the final group, T6 was reduced to 30. 0. The same fates were observed for all the crops, where T1 has provided the highest or the next highest color values signifying the least degradation. This preservation of color is important since color is one of the most defining attributes that determines the 'edibility' and perceived 'renewedness' of the produce by the consumers. The results are relevant to the goals of the present research study that aims at assessing the effectiveness of the enhanced preservation techniques on the quality maintenance. The fact that T1, T2 and T3 were more effective in maintaining color than the control good show that these techniques could go further than to offer an extended shelf life but would also offer a better way of preserving the sensory characteristics of fresh produce. These results get in touch with a shift in the method that is used for preservation of food through embracement of new innovative technologies that improve the sustainability of perishable products.

Table 4: Effect of Different Preservation Techniques on the Color Retention of Berries and Leafy Greens

Crop	T1	T2	T3	T4	T5	T6
Strawberries	36.5	35.8	36.0	33.0	34.5	30.0
Blueberries	28.0	27.5	27.8	25.0	26.0	22.0
Raspberries	40.0	39.2	39.5	36.0	37.5	33.0
Spinach	42.5	41.8	42.0	38.0	40.0	35.0
Lettuce	38.5	37.8	38.0	34.0	36.0	31.0
Kale	39.0	38.2	38.5	35.0	37.0	32.0

Nutritional Content

Comparing the effects of High-Pressure Processing (HPP), Active Packaging, and Edible Coatings to traditional preservation methods like Refrigeration and Freezing, or no preservation at all, has enlightened the information concerning the nutrient preservation of fresh produce and how Vitamin C and Iron are affected from two aspects: Reduction of loss and maintenance of nutrients.

Vitamin C Content: Processing by High-Pressure Processing (T1) retained Vitamin C in strawberries, blueberries, raspberries, spinach, lettuce, and kale; concentrations were significantly different from the traditional method and the control. For instance, HPP of strawberries preserved 60 of Vitamin C/100g as opposed to 40 of vitamin C/100g in the control. In the same manner, HPP behind applied 80 mg/100g of kale retention and better than 65 mg/100g applied in the control group. In general, Active Packaging (T2) and Edible Coatings (T3) proved promising, the Vitamin C concentration in the sample treated with the help of the above techniques was significantly preserved, having much higher values than in samples exposed to Refrigeration (T4) and Freezing (T5) which led to considerable losses. Among control sample (T6), had the lowest Vitamin C content of all the crops, which implied more degradation.

Table 5: Vitamin C Content (mg/100g) of Various Perishable Produce Treated with Different Preservation Techniques

Crop	T1	T2	T3	T4	T5	T6
Strawberries	60	58	59	50	55	40
Blueberries	10	9	9.5	8	9	6
Raspberries	30	28	29	24	27	20
Spinach	30	28	29	25	27	21
Lettuce	15	14	14.5	12	13	10
Kale	80	78	79	70	75	65

Iron Content: When it comes to the amount of Iron being retained, HPP proved superior once again. For instance, strawberries under HPP maintained up to 0. 7 mg/100g of Iron that is seven times as much as turnips and 0. 40 mg/100g in the control which was significantly raised to 60 mg/100g in the treated plant. The same can be said about all the crops with differences between the HPP and the traditional methods being statistically significant. Though both Active Packaging and Edible Coatings were slightly worse than HPP, it was still better than Refrigeration and Freezing. As observed in control samples, nutrient retention available in the samples was significantly low as revealed by the least Iron percentage. These insights confirm the potential benefits of new technologies for preserving the Vitamin C and Iron content in perishable produce more effectively, compared to traditional methods, thus pointing at the potential for improving food quality and shelf life. This study's approach is novel and provides knowledge on how preservation can be enhanced for improved nutritional quality.

Table 6: Iron Content (mg/100g) of Various Perishable Produce Treated with Different Preservation Techniques

Crop	T1	T2	T3	T4	T5	T6
Strawberries	0.7	0.65	0.68	0.50	0.60	0.40
Blueberries	0.2	0.18	0.19	0.15	0.17	0.10
Raspberries	1.0	0.95	0.97	0.80	0.90	0.60
Spinach	2.7	2.5	2.6	2.0	2.3	1.8
Lettuce	1.2	1.1	1.15	0.9	1.0	0.7
Kale	1.5	1.4	1.45	1.1	1.3	0.9

Sensory Evaluation (Overall Acceptability out of 9)

The assessment of innovative methods of preservation and enhancing the shelf life of perishable produce led to differences in the overall acceptability of the combine techniques on the sensory scale. The HHP treatment (T1) was once again seen to have the highest global acceptability scores of all the studied crops with strawberries having 8 out of 10. 5, blueberries 7. 0, raspberries 7. 5, spinach 6. 5, lettuce 6. 0, and kale 7. 0 out of 9. This method retained high sensory characteristics, which also corroborates other findings highlighting the method's advantage of keeping produce fresh and of high quality as opposed to the traditional and control methods.

On the same note, Active Packaging (T2) also had fairly good acceptable scores varying between 6 and 8. 5 to 8 quantity for blueberries. 0 for strawberries, signifying that the gas was very instrumental in the endeavors of enhancing the period of freshness while at the same time enhancing just about all the sensory attributes. Edible Coatings (T3) had moderate efficacy where the scores plotted almost followed Active Packaging, which was, nonetheless, lower than HPP. This is in line with earlier scores where the Control group (T6) was at the very bottom of the acceptability with significantly poor scores for all the crops under treatment impressing the role of treatment on sensory quality in the study. T4 and T5 or Refrigeration and Freezing appeared to be effective differently. On the aspect of sensory qualification, refrigeration yielded better results compared to freezing, but was again inferior to both HPP and Active Packaging, especially with strawberries and blueberries. T5 of Produce typically yielded lower sensory scores for delicate vegetables such as lettuce and spinach because of the changes in texture and possible nutrient leaching. Such findings are appropriate in pointing to the effectiveness of new preservation practices, especially the High-Pressure Processing on the sensory attributes of perishable produce. Of all the studies done, this one points to the reality that it is possible to incorporate these techniques in food preservation for the benefit of the consumers and for minimizing wastage.

Table 7: Sensory Evaluation of Overall Acceptability (out of 9) for Various Preservation Techniques Applied to Perishable Produce

Crop	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**
Strawberries	8.5	8.0	8.3	7.0	7.5	6.0
Blueberries	7.0	6.5	6.8	5.5	6.0	4.5
Raspberries	7.5	7.0	7.2	6.0	6.5	5.0
Spinach	6.5	6.2	6.4	5.0	5.5	4.0
Lettuce	6.0	5.8	6.0	4.5	5.0	3.5
Kale	7.0	6.8	7.0	5.5	6.0	4.0

DISCUSSION

The outcomes of this study would therefore compare the HPP, AP and EC to the conventional and proven methods of preservation such as cold chain namely refrigeration and freezing in terms of shelf life of the perishable produce and their quality. The findings of this study indicate that there is potential for a substantial improvement in microbial inactivation and texture, color, and nutrients' retention using the developed techniques especially HPP. The outcomes of this study show that HPP (T1) was the most efficient of all the techniques under test for the elimination of microorganisms from the crops. The mean microbial loads of strawberries, blueberries, raspberries, spinach, lettuce and kale were considerably reduced on application of HPP treatments compared to active packaging (T2), edible coatings (T3), refrigeration (T4) and freezing (T5) treatments. These results are in, sync with earlier researches that have demonstrated that HPP operates more effectively in terms of microbial eradication and does not harm the produce in any way [16,17]. HPP's capacity to apply high pressure on microbial cells without affecting the quality of the produce is collaborated by other researchers [18]. Regarding texture, HPP caused the least change in the firmness of the produce as compared to other treatments and the control. This result is important because texture is one of the quality characteristics that are most important when it comes to consumers accepting the product. There is evidence that the textural quality of fruits and vegetable is better maintained when treated with HPP than when they are frozen or refrigerated as the later makes the tissues of the fruits and vegetables to have an undesirable texture due to the formation of ice crystals and moisture loss [19]. The texture retention achieved through HPP can be explained by the fact that HPP does not include heat treatment – this leads to such alterations of the tissues' structure, which are undesirable [20].

The other quality attribute, which is of immense importance to the consumers is color retention. The study revealed that HPP, AP, and EC retained color better than refrigeration and freezing, although the study had some limitations and applied methodologies differed. This is in concord with other research showing that HPP retains the natural color of produce better than other methods because freezing for example causes color loss [21, 22]. This might be because HPP has comparatively mild processing conditions which do not harm the pigments, such as anthocyanin or carotenoid [23]. In as much as nutritional content, especially the Vitamin C and Iron, HPP recorded the highest level of retention. This is in consonance with previous studies that has revealed the ability of HPP to retain the sensitive nutrients better than the conventional practices [24]. The fact that Vitamin C and Iron are preserved within HPP-treated produce can be ascribed to the method's blocking of oxidative processes, all the while not requiring heat treatment, which is known to cause nutrient leaching [25]. P>Active Packaging and Edible Coatings also proved beneficial and although they were slightly less effective than HPP, current research also indicate that both methods efficiently preserves the shelf life and nutrients of the food items [26]. Sensory evaluation results indicated that HPP processed produce got the highest overall acceptability scores, this is in agreement with earlier authors who aver that HPP is more preferred by consumer as a method of produce preservation because it maintains the quality [27]. Similar to shelf life attributes, Active Packaging and Edible Coatings also depicted good impact on sensory scores. However, traditionally applied means and controls provided decrease acceptability scores concerning texture and taste; it is consonant with the outcomes showing that refrigeration and freezing cause quality depreciation [28].

Novelty and Practical Implications

As this research aims at comparing novel preservation methods, the originality of this study is in the integration of such preservation methods within a single framework and evaluate their efficacy compared to the traditional methods. Thus, the findings indicate the usefulness of HPP as a superior method in maintaining microbial safety for processed foods, meat texture, color, and nutritional value, signifying potential use in the diverse food industry [29]. Consequently, the study recommends the implementation of HPP and other emerging techniques as a likely technique that would help in enhancing the food preservation and hencereduce wastage, while at the same time improving satisfactions among consumers.

Future Directions

Based on the findings of this research, several directions for the further study of the identified novel preservation techniques can be developed. Firstly, future research can expand these methods of preservation to other food items with special emphasis to exotic fruits and vegetables to determine the techniques' versatility [30]. Furthermore, more research for exploring the likely profitable applications of these technologies and practical implementation of them in commercial organizations facilitates the decision-making intended for applying these technologies in the food chain. Investment could also be directed toward the enhancement of the conditions of HPP so as to achieve the highest results at the lowest use of energy and hence cost. Indeed, this approach may extend knowledge about the impact of one preservation method on another and consequently develop new approaches for improving food quality and, at the same time, its shelf life [31]. Lastly, other research could investigate consumers' perceptions of new preservation techniques as the information could be used to influence the manufacturing and promotional approach to relevant products. Improve of those areas could probably enhance usage of such progressive preservation techniques which would in turn increase sustainability of food preservation [32].

CONCLUSION

This study achieves its aim of comparing New Preservation Technologies with the traditional methods through the investigation of the efficacy of four techniques (High-Pressure Processing, Active Packaging, and Edible Coatings) and how they fare than Refrigeration and Freezing in the protection of the shelf life and quality of versatile produce such as berries and leafy greens. Specifically, HPP was identified as the most efficient method revealing a decrease in microbial load, texture retention, and color, Vitamin C, and Iron content to a greater extent than other procedures. Active Packaging and Edible Coatings also demonstrated significant enhancements over the traditional methods especially in the area of microbial load and nutrients preservation. Such work emphasizes the significance of upgrading preservative in extending shelf-life and increasing quality of perished horticulture products by comparing existing modern preservative technologies, thus, the results can provide a base for future researches on the preservative technologies to reduce food waste. This research therefore addresses gaps in the current literature and proposes potential implementations for industries. The conclusion indicates that High-Pressure Processing (HPP) as the leading method of preservation with more shelf-life benefits and quality retention of the delicate produce than other conventional methods.

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