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RESEARCH ARTICLE

EFFECTS OF CACL$_2$ ON SHELF LIFE AND QUALITY OF *PLEUROTUSOSTREATUS*

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ABSTRACT

The limited durability of mushrooms is a significant obstacle to their commercialization and consumption. The objective was to assess the impact of $CaCl_2$ treatment on production characteristics such as dry matter, yield, colour, firmness, wet loss, and tissue calcium content in three consecutive flushes. The study involved applying five concentrations of$CaCl_2$ irrigation treatments (0.35%, 0.45%, 0.55%, 0.75%, and 1.00% $CaCl_2$) as well as tap water (control) to the *Pleurotusostreatus* white strain,for 8 days at 4^{o}C. The statistical analysis of the data indicated that $CaCl_2$ treatment enhanced the dry matter content, increased the concentration of Ca in the mushroom tissue, and enhanced the colour, and firmness, reduced wet loss, but had little impact on the yields. A linear relation was observed between the amount of $CaCl_2$ used and the shelf life and quality of mushrooms. The highest Ca content was found in mushrooms treated with 0.75% and 1.00% $CaCl_2$. Concentrations of 0.35%, 0.75%, and 1.00% were seen to delay the softening of mushrooms, resulting in increased firmness, preserving freshness by preventing the occurrence of browning throughout their shelf-life. Treating the mushrooms with $CaCl_2$ solution for 8 days at 4^{0}C could be used as asustainable production approach that could help to increase the shelf life and postharvest quality of *Pleurotusostreatus*, to boost its commercialization and consumption.

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INTRODUCTION

Nigeriais currently confronting significant obstacles to ensuring food security,which stem from issues such as climate change, decline in soil fertility and subsequently, low crop yields. To address these problems, Nigerians must increase agricultural productivity, such as mushrooms to meet the needs of its rising population. Oyster mushroom (*Pleurotusostreatus*) has been recognised as a highly promising food source for addressing malnutrition due to its rapid growth, efficient use of agricultural wastes, minimal area requirements, and low water consumption in comparison to other crops. *Pleurotusostreatus* is regarded as one of the most popular mushrooms worldwide and is grown on a large scale across the globe due to its exceptional flavour and its beneficial effects on health and nutrition (Tesfaw*et al*., 2015; Yao *et al*., 2019). *Pleurotusostreatus* is a significant provider of protein, carbohydrates, vitamins, and mineral components. Itserves as a meat alternative in vegetarian diets. In addition, mushrooms possess a substantial amount of dietary fibre and have immune-stimulating and anticancer properties due to their chemical composition (Lemieszek and Rzeski, 2012; Cheung, 2013). They also demonstrate antidiabetic, antioxidant, and antitumor effects (Meng *et al*., 2016; D´avila *et al*., 2020). The diverse phytochemicals, enzymes, primary metabolites, and secondary mycometabolitescotents contributes to a limited shelf-life, rapid decay, and significant postharvest losses (30–35%) (Prasad Thakur *et al*., 2022). Freshly cut mushrooms undergo several physiological processes during storage, such as senescence, wilting, shrivelling, and browning, primarily caused by rapid water loss (Prasad Thakur *et al*., 2022).

These processes lead to a decline in both commercial and nutritional values (Mahajan *et al*., 2008; Diamantopoulou and Philippoussis, 2015). The most harmful alterations in terms of post-harvest quality of mushrooms are the reduction in whiteness, changes in surface colour, and softening of the tissue (Mahajan et al., 2008). Displaying pristine, white-coloured mushrooms to customers at retail establishments has been demonstrated as an effective strategy for boosting sales. Discovering methods to enhance and sustain the whiteness of mushrooms holds the capacity to increase sales and minimise waste. Various techniques, including chilling, washing with antimicrobial chemicals, stipe trimming, modified environment packaging, and irradiation, have been used to manage and slow down the process of post-harvest deterioration and enhance the shelf-life of products (Kexin Zhang *et al*., 2018). The application of post-harvest treatments can effectively delay the ageing process of mushrooms and extend their shelf-life. However, the quality of the mushrooms during storage mostly depends on the quality attributes at the time of harvest, which can be significantly improved through cultivation practices (Miklus andBeelman, 1996). Calcium is a crucial mineral that promotes a range of biological processes, such as growth and the accumulation of important substances including phenolics, flavonoids, polysaccharides, enzymes, and minerals, in mushrooms (Tang *et al*., 2023). Therefore, the objective of this study is to assess the impact of calcium chloride on the duration that mushrooms remain fresh and their qualitative attributes during both the harvesting and storage stages.

MATERIALS AND METHODS

Experimental site: The trial took place at the botanical garden of Imo State University, located at 5°29'1"N 7°1'60"E in the humid rainforest ecosystem of Nigeria. The *Pleurotusostreatus* white strain was acquired from the commercial market and subsequently propagated in the laboratory of the Department of Plant Science and Biotechnology.

Preparation of a solution of calcium chloride: Calcium chloride ($CaCl_2$) was dissolved in deionized water, and subsequent dilutions were performed to achieve various concentrations of $CaCl_2$ (0.35%, 0.45%, 0.55%, 0.75%, and 1.00%).

Cultivation of mushrooms: The *Pleurotusostreatus*white strain was cultivated using the conventional MTDF cropping techniques, as outlined by Miklus and Beelman in 1996, and Tavarwisa*et al*. in 2021, with certain adjustments. The wheat straw, which served as the base substrate material, was subsequently cut into pieces measuring 2-3 cm in length.

Application of calcium chloride solution: The study applied various concentrations of $CaCl_2$ (0.35%, 0.45%, 0.55%, 0.75%, and 1.00%) and tap water (control) to *Pleurotusostreatus* from the pinning stage to harvesting, as described by Philippoussis *et al*. (2001) and Contreras *et al*. (2017), with some modifications. The bags were moistened by spraying water on them, and the floors were also dampened to raise the humidity while maintaining the temperature at 4^0C.The mushrooms were collected at approximately 7:30 a.m. on the day with the highest production throughout each growth cycle, right before the usual harvest.

Colour measurements: The mushrooms were chosen based on their size (30-40 mm in diameter), maturity (stage 1), and lack of bacterial blotch. The same target colour used for "at harvest" colour evaluation was also used to evaluate the colour in postharvest storage. The L*, a*, and b* values of mushrooms during storage were measured using a Minolta Colourimeter (CR-400 Model Colourimeter, Konica Minolta Sensing, Inc., Osaka, Japan). The device contains two standard illuminants (C and D65) and a standard colourimetric observer (2°) inside (Nakilciolu-Tas and Otleş, 2020). Three color measurements were taken on each mushroom which yielded 15-18 readings for each treatment. The average of the packages was used to calculate a postharvest storage colour reading for each treatment for each flush.

Dry matter measurement: Four mushrooms were subsequently weighed, transferred onto an aluminium weighing dish, placed into a freezer at a temperature of -20°C, and then covered. From a single harvest day, 32 quarters produced a total of eight whole mushrooms, which were then frozen. The frozen samples underwent freeze-drying for a duration of 48 hours using a VirTis 15-SRGX freeze-drying model. The freeze-dried samples were promptly measured, moved into a 2 oz Whirl-Pak® sterile sampling bag (Nasco Co.), and placed inside a desiccator. The solid content was expressed as the percentage of dry matter relative to the fresh weight.

Measurement of calcium accumulation: The freeze-dried mushroom tissue that was left over after determining the solids content was utilised for calcium analysis. The samples were kept in a desiccator until they were analysed.The impact of $CaCl_2$ treatment on the Calcium concentration in the harvested mushroom was assessed by analysing tissue separations from the second batch, using atomic emission spectroscopy.

Total yield: Was measured in terms of the fresh weight (kg) of the mushroom.This was determined using the total weight of fresh mushrooms from all flushes. The total weight of the mushrooms was determined. Next, determine the total weight of the harvested dry substrate.

Total weight=WM / WDS X 100

Weight loss was determined by dividing the weight change in storage by the original weight. The resulting weight loss is expressed as a percent weight loss.

Weight loss (%) = W0 − Wt W0 × 100 (2) where W0 is the initial mushroom weight and Wt is the mushroom weight at selected times (days) during the storage period.

Firmness: Firmness was expressed in N and measured according to Arazuri *et al.* (2007**),** using Texture Analyzer (Stable Micro-System Texture Analyzer Model TA-HDi), from the compressive strength of the cap, applying a 35 mm diameter aluminium probe at 0.5 mm s^{-1} speed. The firmness mean was obtained using the analysis of ten mushrooms.

The experimental design employed a randomised block approach, with treatments of CaCl2 at concentrations of 0.35%, 0.45%, 0.55%, 0.75%, and 1.00%, as well as a control treatment using tap water. The experiment was replicated three times.

Statistical analysis: The obtained data on preharvest and postharvest quality assessments, as well as calcium accumulation, were subjected to statistical analysis using analysis of variance (ANOVA). The statistical significance of mean differences was evaluated utilisingTukey's honestly significant difference (HSD) test ($p < 0.05$) through the utilisation of MINITAB 20 software.

RESULTS AND DISCUSSION

The dry matter content: The dry matter content exhibited a positive correlation with the concentration of the applied calcium chloride. The findings corroborated the research conducted by Van Loon *et al*. (2000), which emphasised the significance of dry matter content as a key indicator of mushroom quality. Furthermore, the study demonstrated that the use of calcium treatment expanded the range of dry matter content. In addition, Kałużewicz*et al*. (2015) found that the use of calcium chloride at concentrations of 0.4% and 0.6% increased the dry matter content of the carpophores of two mushroom strains, Amycel 2200 and Italspawn F59. (Table 1).

Total yield: The application of $CaCl_2$ to mushrooms had no noticeable impact on the overall yield. The findings were in line with Philippoussis et al (2001), who concluded that varying amounts of calcium chloride had no significant impact on the overall yield and the yield generated over the study period (Table 1).

Weight loss (%): The weight loss of mushrooms shown an increase over the course of storage. The reduction in mushroom weight loss due to CaCl2 treatment can be related to the role of calcium in preserving cellular structure and regulating enzymatic activities. This helps to slow down the moisture loss induced by senescence (Jayathunge and Illeperuma, 2005). (Refer to Tables 1 and 2).

Colour: The addition of CaCl2 intensified the pigmentation of the mushroom throughout the duration of the research.The whiteness of fresh mushrooms treated with $CaCl_2$ ranged from 45.0 to 60.40. The measured values fell within the range of findings reported by Wan-Rosli (2011), who examined the variations in textural and optical characteristics of oyster mushroom (Pleurotus spp.). Colour is the first and most apparent factor in determining the quality of fruits and vegetables. It serves as the initial measure for customer approval (Zalewska et al., 2018). A reduction in colour value is a clear indication of mushroom browning. The treatment with $CaCl_2$ increased colour intensity, possibly because calcium influences the integrity of vacuole membranes and slows down enzymatic browning (Roy et al., 1996) (Tables 1 and 2).

Weight loss (%): $CaCl_2$-treated mushrooms reduced the weight loss of mushrooms during the storage period. The reduction in mushroom weight loss due to $CaCl_2$ treatment can be related to calcium's role in preserving cellular organisation and controlling enzyme activities,

Table 1. Effects of calcium chloride on Mushroomquality characteristicsat harvest

	Totalyield	Firmness(N)	Colour(%)	Calcium contents (mg/kgdryweight)	Drymatter
Calcium concentrations					
0.35%	17.58a	4.34b	60.23b	197c	7.04c
0.45	17.73a	4.66b	60.40b	199c	7.45c
0.55	18.06a	5.78a	60.44b	207b	9.54b
0.75	17.54a	5.66a	61.00a	243a	9.70b
1.00	18.05a	6.50a	61.40a	255a	11.23a
Tap water	18.00a	2.44c	58.00c	154d	6.04d

Table 2. Effects of $CaCl_2$ on Mushroom quality characteristics during storage

	Weightloss(%)	Firmness(N)	Colour	Calciumcontents(mg/kgdryweight)
Calcium concentrations				
0.35%	8.05b	3.04c	58.23b	195c
0.45	6.22c	3.26c	58.40b	193c
0.55	5.04d	4.06b	58.44b	205b
0.75	5.07d	5.66a	59.20a	240a
1.00	4.03e	5.40a	60.40a	248a
Tap water	56.33a	1.24d	45.00c	130d

therefore slowing down the moisture loss induced by senescence (Jayathunge and Illeperuma, 2005) (Table 2).

Firmness: The increase in mushroom firmness with $CaCl_2$ treatment aligns with the findings of Khademi and Khoveyteri-Zadeh (2022) in their study on button mushrooms. The firmness of the mushroom meat is closely linked to its texture and serves as a key determinant of its market value post-harvest. It also indicates the deterioration of the produce and the reduction in its water content. The firmness of mushrooms significantly impacts their shelf life (Lin et al., 2017). Calcium supplementation has been found to increase the rigidity of the cell membrane in fruits and vegetables and restrict the softening of the flesh (Jiang *et al*., 2013). The use of $CaCl_2$ dipping has been reported to protect the cell wall and middle lamella structure, as well as enhance the texture of fresh food (Luna-Guzman and Barrett, 2000). Post-harvest calcium treatment prevents the formation of water-soluble pectin by forming calcium pectate, which helps maintain the firmness of the produce (Wen *et al*., 2018) (Tables 1 and 2).

In conclusion, the application of calcium chloride resulted in an improvement in the dry matter content, an increase in the calcium concentration in the mushroom tissue, and an enhancement in its colour and firmness. However, it had minimal effect on the yields. The mushrooms treated with 0.75% and 1.00% $CaCl_2$ had the highest calcium content. Observations revealed that mushroom shelf life was enhanced by concentrations of 0.35%, 0.75%, and 1.00%, leading to a sustained improvement in firmness during the duration of their storage. Solutions of $CaCl_2$ with concentrations of 0.75% and 1.00% successfully preserved freshness by inhibiting the process of browning. Applying an 8-day treatment of $CaCl_2$ solution to mushrooms at a temperature of 4^0C can serve as a sustainable production method to enhance the shelf life and postharvest quality of Pleurotusostreatus. This strategy has the potential to promote its commercialization and consumption.

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