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Full Length Research Article

EXPLORING COST-EFFECTIVE METHODS FOR EXTENDING SHELF LIFE OF THREE PEPPER VARIETIES (*CAPSICUM SPECIES* L) PRODUCED IN KWADON, YAMALTU DEBA, GOMBE STATE – NIGERIA

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ABSTRACT
The aim of the study was to identify problems affecting the shelf life of pepper produced in Kwadom, Gombe state Nigeria. Data was generated through the administration of one hundred (100) structured questionnaires to farmers and traders. Physical treatment (perforated carton, and mango leaves) and biochemical (Aloe vera) solutions were investigated to determine the most effective approach of prolonging the shelf life of three pepper varieties (Capsicum abbreviatum, Capsicum grossum and Capsicum glabrisculum L). Biochemical data was obtained in the laboratory using Aloe vera extracts on each pepper variety at various concentrations (0.5, 1.0 and 1.5 %). The result showed that spoilage is variety related with Capcicum grossum having the ability to last longer in storage. The result obtained revealed that aloe vera has positive effect on some varieties with increase in concentration except for Capsicum glabrisculum. Samples covered with leaves and carton did better than controls. Post-harvest practices such as handling, transportation, packaging and storage were found to be the most common challenges of pepper production. This study underscores the notion that pepper is not shelf stable. If properly applied, Aloe vera could be potentially viable as a preservative of post-harvest fruits and vegetables..

Keywords: Shelf life, Pepper, Spoilage, Capsicum species, Aloe vera, Post-harvest, Storage.

INTRODUCTION

Pepper *(Capsicum* species) is an important agricultural crop, widely valued for their nutritional, economic and medicinal properties. They belong to the family *Solanaceae,* a source of natural carotenoids lipophitic (yellow, orange or red pigments) found in plants, algae and microorganism. This pigments play an important role in protecting tissue from light and oxygen damage (Garuba *et al*., 2022). Pepper is an important agricultural crop in Nigeria and many countries not only because of its economic importance but also due to the nutritional and medicinal value of its fruits as well as being an excellent source of natural colors and antioxidant compounds (Howard *et al*.,2000, Jayaprakasha *et al*., 2012).

Shelf-life is the period of time which starts from the time of harvest and extends up to the start of denaturing of fruit and it is the basic quality of fruit durability and the most important factor that accounts for post-harvest losses of fruits **(**Abdurrahman *et al*., 2024). Quality degradation is directly related to losses in fresh horticultural produce (Sharma *et al.*, 2018). This has been previously linked to the following; improper handling, mode of transportation and storage or packaging before sales (Kumar *et al*., 2015). Like other vegetables, sweet peppers are quite perishable; about 38.7% and 28.6% post- harvest losses were reported during the wet and dry seasons, respectively (Tunde-Akintunde *et al*., 2005).
Naturally, most varieties of pepper can stay up to 3-4 days under favorable conditions and temperatures. However, this varies between varieties and season. In hot weather, pepper can stay for 3 to 4 days before it starts deteriorating but stays for a week before physiological (physical) changes become noticeable while still in storage in cold weather (Sharma *et al*., 2018). Researchers have used different methods to prolong shelf life of pepper such as the use of evaporative cooling systems (Dadhich *et al*., 2008; Olosunde *et al*., 2016; Krasnow and Ziv 2022) and have gotten positive results but these systems are not affordable to all farmers. This study seeks to explore possible clean or zero energy alternatives and cost effective ways to prolong the shelf life of pepper that can be affordable to all.

Harvested fruits and vegetables are usually exposed to surrounding temperature during transportation, storage and sales (Brecht *et al*., 2003; Ilic *et al.,* 2012; Oh and Koh, 2018). Freshly harvested peppers must be stored between 7 to 10° C and 95 % relative humidity and the typical storage life of peppers under these conditions is 3-5 weeks (Brechet *et al*., 2003). Water loss is among the main physiological factors that negatively impact pepper fruit during shipment and storage and subsequent marketing (Maalekuu *et al*., 2002; Manzoor *et al*., 2020). Conditioning vegetables and fruits in adequate temperature throughout the post-harvest period is probably the best way to maintain their quality (Brecht *et al*., 2003). Temperature is probably the most important factor affecting the shelf life of bell pepper among others (Garuba *et al*., 2022).
Post-harvest losses of vegetables can be reduced by prolonging the shelf-life of vegetables (Talukder, 2002). When striving for improved food security in developing countries, reduction in post-harvest losses of perishables is of major importance (Kader, 2005; Abdurrahman *et al*., 2024). Several techniques and methods have been employed to help prolong the shelf life of some common vegetables and fruits (Ochoa-Reyes *et al*., 2021). Key among them is the use of Aloe vera (Valverde *et al*., 2005; Serrano *et al*., 2006: Ramachandra and Rao, 2008; Ahmad *et al*., 2009; Marpudi *et al*., 2011; Misir *et al*., 2014; Salama and Aziz, 2021; Lwin *et al.*, 2022); and thermal treatment (Shotorbani *et al*., 2013) The economic importance of pepper cannot be over emphasized as this is crucial

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to both farmers and the nation at large with regards to food security and periodic income (Asiru *et al*., 2018). However, poor harvest methods, storage, packaging and transportation reduce the durability and shelf life of this produce leading to great losses after harvest (Li *et al*., 2018). A study to identify best practices to mitigate these losses is therefore imperative as lots of resources are spent on maintenance practices such as irrigation, fertilizer application and crop protection. It would be quite unfortunate if all are lost after a few days of harvest.

The aim of the paper is to identify problems associated with the shelf life of pepper produced in Kwadom Yamaltu - Deba local government area of Gombe state Nigeria by investigating the effect of aloe vera gel and traditional covering materials such as mango leaves, and perforated cartons, on prolonging the shelf life of three varieties of pepper. The research integrates laboratory controlled experiments with a survey data from farmers which provide comprehensive understanding of post-harvest challenges and practical solutions. We seek to provide useful insights to how best farmers and traders can prolong the shelf life of pepper, thereby improving their economic returns and fortunes (Asiru *et al*., 2018). The site was chosen because of the high incidence of cultivation of pepper.

METHODOLOGY

Study Area

Kwadon is an area within Yamaltu Deba Local Government area of Gombe State. It lies within 10^0 00N, 10^030'N and 11^015'E to 11^045'E, and it is situated in the eastern part of Gombe State. The climate of Yamaltu Deba is part of the extreme tropical continental type. One of the basic characteristics of this climate is relatively short rainy season and comparatively long dry season. Rainfall ranges between 850 to 1000 mm^3 and the rainy season last between 5 to 6 months. Temperature is at its peak during the dry season and ranges between (21 to 39^{o}C). (Oruonye *et al.,* 2016).

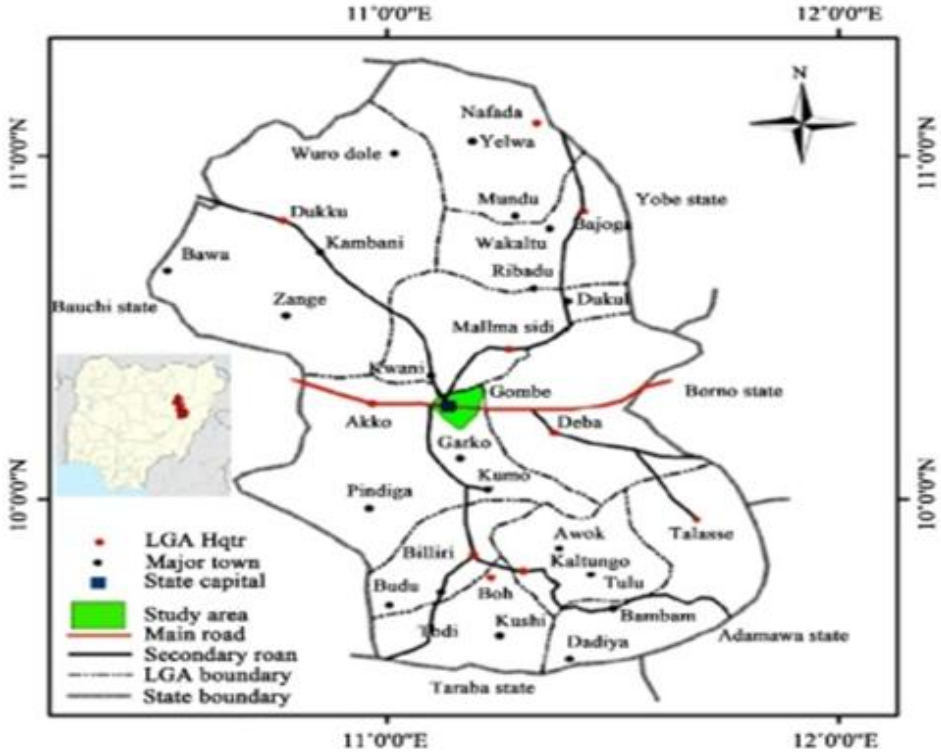

Fig1: Map of The Study Area Credit Research gate

A total of one hundred (100) structured questionnaires were administered to farmers and traders in Kwadom market, Gombe to collect data on harvest, transportation and local methods of prolonging the shelf life of pepper. The data were gathered through survey, personal interview and questionnaires. The information obtained from the farmers was validated experimentally. Fresh pepper fruits of the different varieties used *(Capsicum abbreviatum, Capsicum grossum* and *Capsicum glabrisculum*) were harvested with hand gloves to avoid contamination and conveyed to the laboratory in polythene bags. Rubber trays which were then sterilized with spirit in the laboratory and baskets were bought from the Kwadom market and conveyed to the laboratory. Matured Aloe vera plants used in treatment of the various varieties of pepper were harvested from home garden and also conveyed to the laboratory.

Two physical methods for prolonging the shelf life of the pepper, were tested using two different covering (packaging) materials; fresh mango leaves and perforated biscuit cartons. Aloe Vera was applied at three different concentrations, with untreated fruit serving as the control group. The fruits selected for the experiment were free from defects such as diseases and mutilation.

First basket of each variety was covered with mango leaves and the second baskets were covered with perforated carton and the third left uncovered as control. Twenty (20) fruits each was used

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for each treatment and control. To test for biological preservation method, same quantity and quality of each variety were placed on rubber trays and treated with different concentrations (0.5, 1.0, 1.5 %) of aloe vera gel with others untreated as controls. All treatments/controls were observed for changes for a period of ten (10) days. The following physical parameters were recorded: Shrinking, rotting and discoloration.

Preparation of Aloe Vera Coating solution

After separating aloe vera gel from the outer cortex using a knife, this colorless hydro parenchyma was scraped and blended using an electric fruit blender. The mixture was then filtered with fine net in a conical flask to remove fibers. The experiment comprised of six treatment aloe vera gel solution of 0.5%, 1%, 1.5%, Then the 0.5%, 1%, 1.5% aloe vera gel solution was prepared by dissolving 40 ml, 80 ml, 120 ml aloe vera gel in 1 L water each (Enab, 2012).

Application of Experimental Treatments

Samples from each variety were dipped in different concentrations of the aloe vera gel and allowed for four (4) m, before they were removed placed on clean new rubber trays in the laboratory to dry, then observed for ten (10) days, while taking daily records of the physical changes throughout the observation period.

Data analysis

The data collected from the farmers and traders was analyzed using excel for initial exploration. Further analysis was performed using SPSS version 19.0. Since the data was categorical, simple descriptive statistics was used. The result was presented as frequencies, means and counts, which were displayed in tables and charts. To determine the effect of the treatment, the formula c = t was used to indicate no effect, while T > C, and T < C was used to present positive and negative changes, respectively. T stands for treatment and C stands for control samples.

RESULTS

To understand the cultural practices and application of modern methods of storage, we investigated the level of literacy of the respondents. Results show that 44% had attended primary, 22% had attended secondary while 34% never had any formal education (Table 1).

Table 1. Literacy Level of Respondents (Farmers and Traders)

Respondents	Frequency	Percentages
Level of Literacy		
Primary	44	44
Secondary	22	22
Tertiary	0	0
No formal Education	34	34
Total	100	100

Post-Harvest Practices

The condition of fruit maturity was investigated and it was found that 54% of the farmers admitted to harvesting their pepper when fully ripe, 11% semi ripe, while 35% harvested either as semi or fully ripe. (Table 2 b). Results also revealed that 65% harvested during morning, 7% in the evening and 28% at no specific time of day (Table 2 a). The mode of picking was investigated and results show that 70% picked pepper fruits without hand gloves while 30% picked fruits with gloves (Tables 2 c). The method of fruit transportation revealed that 42% transport pepper fruits using sac by car, 33% transports fruits using basket by car, 17% transport fruits using baskets placed on their head and 8% using sac placed on their head. (Table 4 a).

Perceptions of Respondents

Ninety one percent (91%) of the respondents believed that damage is variety related while (9%) respondents were of a contrary opinion (Table 5 b). Longevity in storage was investigated and (19%) agreed that *Capsicum abbre*viatum lasts longer in storage than other varieties, (80%) went for *Capsicum grossum* while, (1%) choose *Capsicum glabrisculum* (Table 5 c)..

Physical and bio-chemical treatments

The efficacy of covering materials was tested and it was found that those treated with carton and leaves were better than the control samples (fig 2 - 4). Samples responded positively in terms of shrinking with increase in aloe vera gel concentration for *Capsicum abbreviatum* and *Capsicum grossum* (Fig 3) but reverse was the case with *Capsicum glabrisculum* (Fig 3). For colour change, *C.grossum* responded favorably to Aloe vera treatment at 1.5 mL with no change in colour up to the 8th day and only 10 % change in colour at the end of the observation period (Fig. 4). The other two varieties where better off with physical treatment and maintained colour up until the 6th and 7th day for *C. abbreviatum* and *C. glabrisculum* respectively.

Rotting of fruits was better tackled using 1.5 mL Aloe vera concentration for *C. abbreviatum*, while *C.grosum* responded positively to treatment at all concentration (Fig 2). With physical treatment, *C. grosum* responded positively with leaves than with carton. Conversely, *C. glabrisculum* did better with physical treatment than with Aloe vera at higher concentration (1.0 and 1.5 %) (Fig 2).

Table 2: Time of harvest, stage of harvest and method of picking by the respondents

Respondents	Frequency	Percentages
(a) Time of Harvest		
Morning	65	65
Afternoon	0	0
Evening	7	7
Anytime	28	28
Total	100	100
(b) Stage of Harvest		
Ripe	54	54
Semi-ripe	11	11
Both	35	35
Total	100	100
(c) Method of picking pepper fruits		
With Hand Gloves	30	30
Without gloves	70	70
Total	100	100

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Table 3: Product post-harvest packaging, road condition and distance to market as factors affecting shelf life

Respondents	Frequency	Percentages
(a) Covering with Leaves		
Yes	48	48
No	52	5
Total	100	100
(b) Are farm roads good?		
Yes	0	0
No	100	100
Total	100	100
(c) Are markets far from farms?		
Yes	85	85
No	15	15
Total	100	100

Table 4: Modes of transportation, effect of overloading and storage limit by the respondents

Respondents	Frequency	Percentages
(a) Mode of Transportation		
Basket in Car	33	33
Basket hand Borne	0	0
Basket head Borne	17	17
Sac in Car	42	42
Sac Head Borne	8	8
Total	100	100
(b) Does overloading affect Fruits		
Yes	100	100
No	0	0
Total	100	100
(c) Storage Limit (Days)		
2 – 4 days	100	100
4 – 7 days	0	0
Otherwise	0	0
Total	100	100

Table 5: Process of keeping harvested product before sales, damage and longevity across varieties

Respondents	Frequency	Percentages
(a) Process of Storage before Sales		
Basket in open air	38	38
Covered	0	0
Sac open air	0	0
Open air	62	62
Total	100	100
(b) Damage Variety Related?		
Yes	91	91
No	9	9
Total	100	100
(c) Longevity Variety Related?		
Capsicum abbreviatum	19	19
Capsicum grossum	80	80
Capsicum glabrisculum	1	1
Total	100	100

Table 6. Physical signs, knowledge and practice of traditional method of storage and traditional method by respondents

Respondents	Frequency	Percentages
Physical Signs observed		
Shrinking	59	59
Busting	5	5
Color Change	7	7
Fungal Growth	4	4
Rotting	25	25
Total	100	100
Knowledge of traditional Storage Methods		
Yes	85	85
No	25	25
Total	100	100
Traditional Storage methods		
Drying	19	19
Grinding	80	80
Otherwise	1	1
Total	100	100

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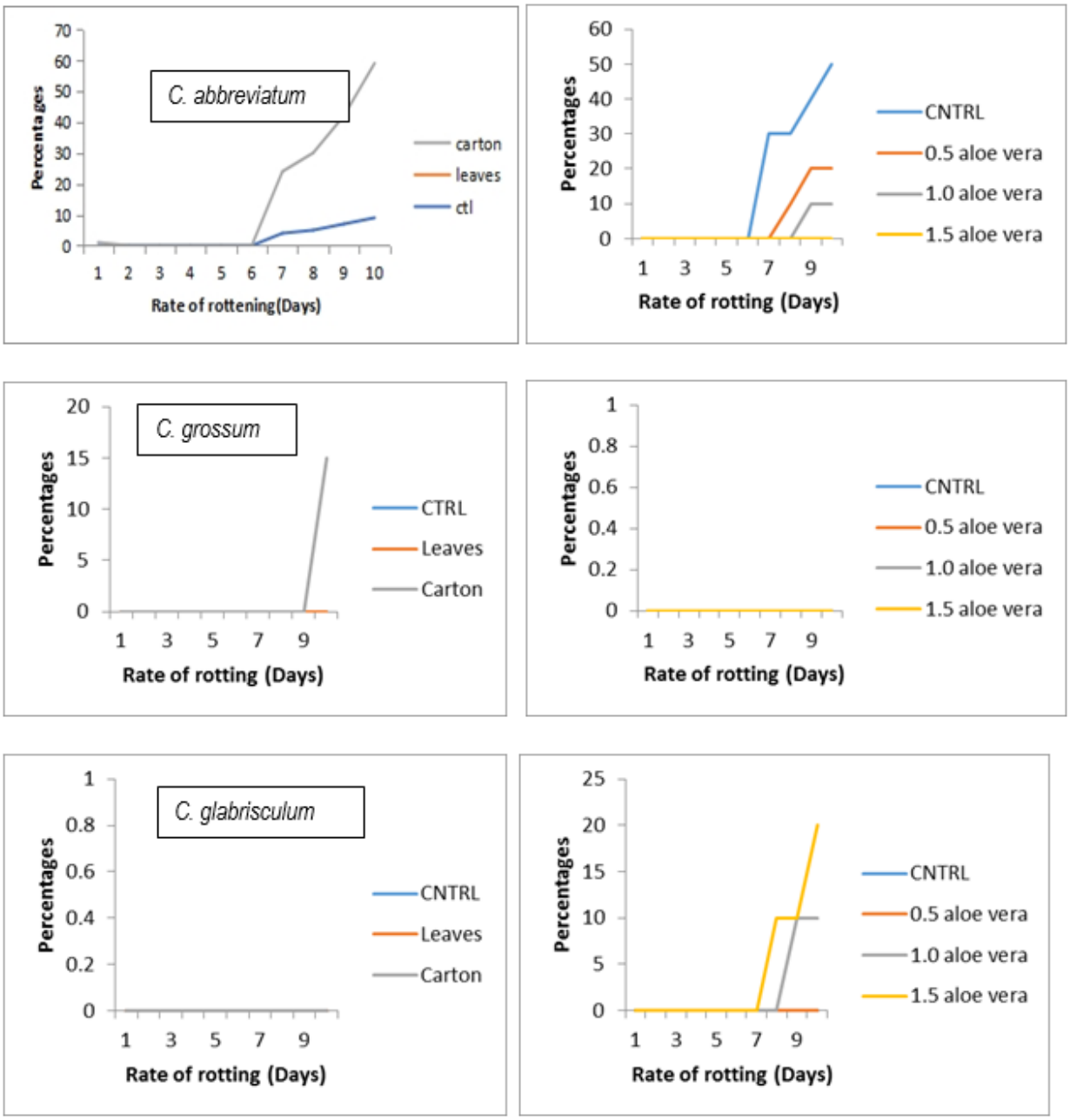

Fig 2: Variation in rotting rates with physical (left) and Aloe vera (right) treatment across the three varieties

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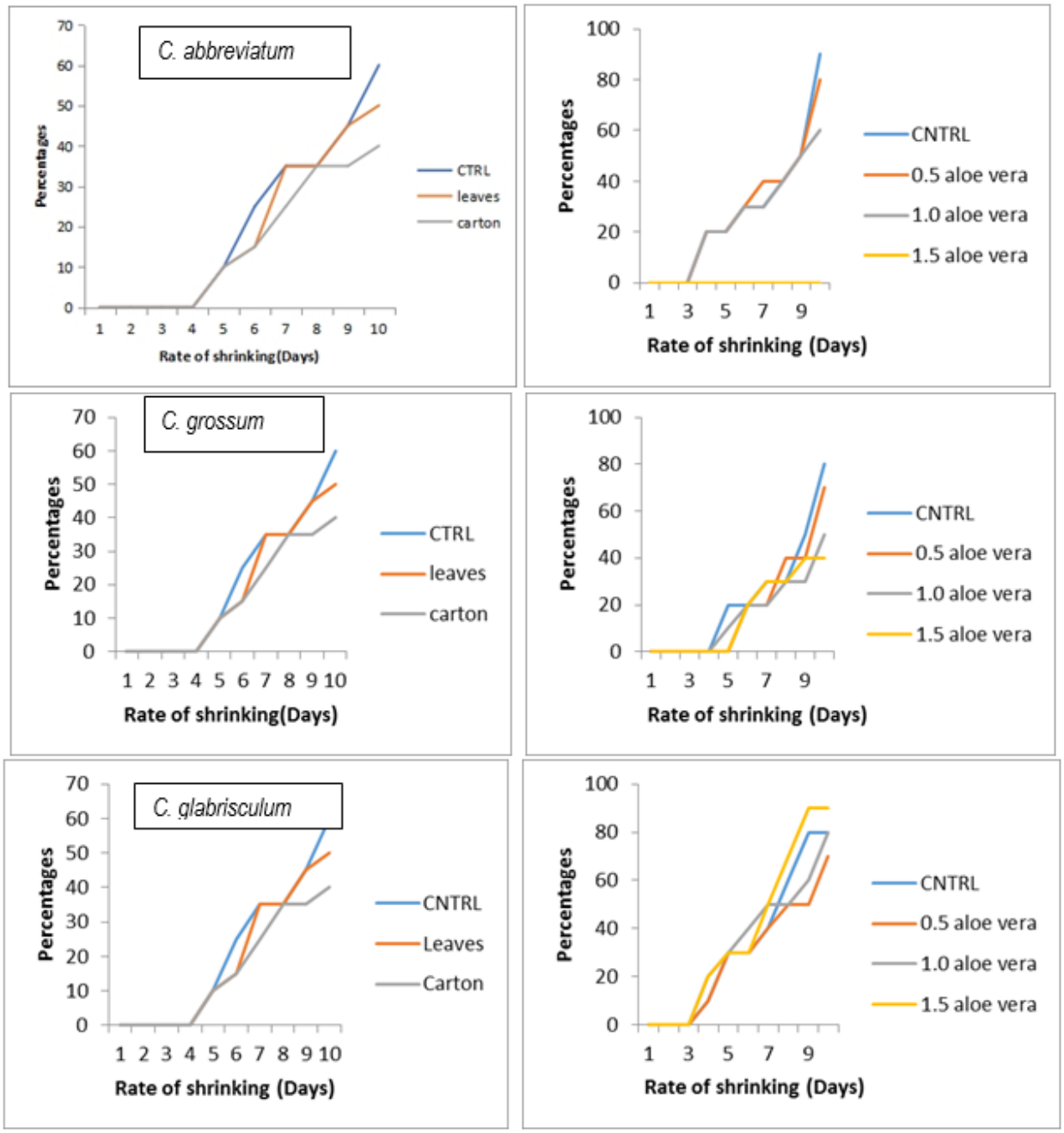

Fig 3: Variation in shrinking rates with physical and Aloe vera treatments for the three varieties

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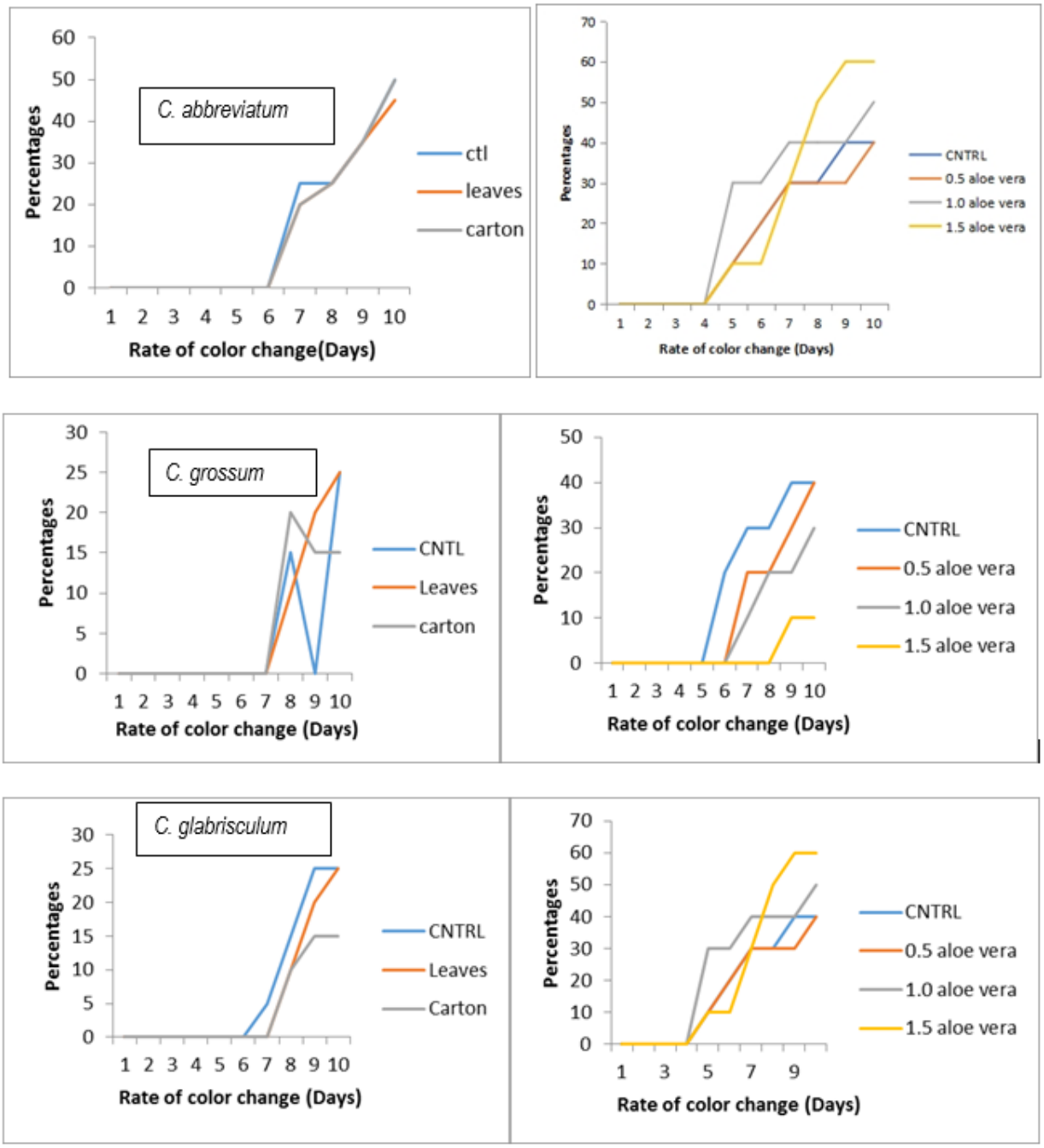

Fig 4. Variation in rates of color change with physical and Aloe vera treatments for the three varieties

DISCUSSION

This study highlights critical factors influencing the shelf life of Capsicum species produced in Kwadon, Yamaltu Deba. The findings confirm that post-harvest spoilage is multi-factorial, with significant contributions from handling, transportation, and storage practices (González *et al*., 2003), as well as inherent variety-specific differences (Dessie *et al*., 2022). The preference for harvesting fully ripe peppers, driven by market demand, contradicts the recommendation by Wilson *et al*. (1995) that semi-ripe harvesting extends shelf life. While harvesting practices were mostly aligned with cooler early morning temperatures, the lack of hand glove use by most farmers could explain higher spoilage rates, emphasizing the role of hygiene in post-harvest management (Ochoa-Reyes *et al*., 2021).

The effectiveness of traditional methods, such as covering peppers with mango leaves, is supported by Leon *et al*. (2013), who identified temperature control as critical in maintaining freshness.

The experimental evidence further validates this, showing reduced spoilage in mango leaf-covered samples compared to controls. However, the less favorable results with perforated cartons for *Capsicum glabrisculum* suggest variety-specific differences in response to covering methods, aligning with Samira *et al*. (2013) and Li *et al*., (2018).

Aloe vera gel treatments demonstrated potential in prolonging shelf life, with 1.5% concentration proving most effective for Capsicum abbreviatum and Capsicum grossum. These findings are consistent with Valverde et al. (2005) and Martínez-Romero et al. (2006), who reported similar benefits of aloe vera for other horticultural products. However, the reduced efficacy for *Capsicum glabrisculum* highlights the complexity of variety-specific preservation strategies and warrants further investigation. The findings have direct implications for farmers and traders in developing regions. Adoption of cost-effective traditional methods, such as covering with mango leaves, could significantly reduce post-harvest losses (Oh and Koh, 2019). Similarly, the use of aloe vera gel as a natural preservative offers an environmentally friendly alternative to synthetic options, aligning with sustainable agricultural practices (Salama and Aziz, 2021). However, its application requires in-dept understanding of the active compounds that provide the pathway for its biochemical activity as a preservative (Ahmed and Hussain, 2013).

The results also underscore the need for infrastructural development such as good roads and transport systems to enable marketers and farmers move products in good time and condition to end-users. The northern region with its high temperature and low humidity needs to adopt sustainable nature-based solutions to tackle post-harvest loses. Based on the results of this study, these measures should be species-specific not generalized (Lwin *et al.*, 2022).

It will be worthwhile also to apply chemical treatment after at least four days of harvest and storage considering most varieties begin to denature (change color, shrink or rot) after about four days even before they are subjected to various physical treatments. This measure will ensure that bio-chemical treatment (use of preservatives) is not wasted for species that may be utilized within a short period after harvest. Future research should consider a combination of treatments, both physical and bio-chemical preservatives at various concentrations across a broad range of species (Aramyan and Gogh, 2014). Temperature and relative humidity are factors that may interact to mute the effects of certain treatments. These abiotic factors are crucial in the tropics and ought to be controlled or factored into the experimental set up to avoid the interplay of confounding factors.
The study's scope was limited to three Capsicum varieties and a single geographic region, which may restrict the generalization of results. Additionally, the effectiveness of aloe vera gel was not tested across different environmental conditions or with extended observation periods. Future research should explore these variables and assess applicability for commercial use.

Conclusion

Capcicum abbreviatum, Capsicum glabrisculum and Capsicum grossum are the most common varieties grown and sold in Kwadom. Spoilage or fruit denaturing is variety related with respect to seasons with Capsicum *grossum* having the capacity to stay longer if handled properly. Carton and mango leaves have the ability to prolong shelf life of *Capsicum abbreviatum* and Capsicum *grossum* as those covered were better than those left opened. However, Capsicum *glabrisculum* did better when left opened than when covered. It was revealed that drying is the traditional method used by most farmers and traders to preserve pepper. The study also revealed that aloe vera gel seems to have positive effect on some varieties of pepper as it did on papaya, mango and berry despite the differences in families and also differences in the geographical location. However, the results of this study suggest that the gel will have better effect with increase in concentration, despite being less effective on *Capsicum glabrisculum* variety. Overall, the results of this study show that post-harvest activities accounts for the quick spoilage of pepper irrespective of treatment.

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