Sodium Hypochlorite Combined with Calcium Chloride and Modified Atmosphere Packaging Reduce Postharvest Losses of Hot Pepper

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Abstract: A ‘systems approach’ was used to investigate changes that would enhance final produce quality and reduce postharvest losses of hot peppers. A survey of producers and traders was completed at seven market outlets in Trinidad. The major technological and socio-economic constraints leading to quality deterioration and postharvest losses were investigated in the survey and tested experimentally to develop solutions for quality maintenance and management. As fruits moved through the various steps in the postharvest handling system in the various market outlets, there were declines in marketable quality resulting in qualitative and quantitative losses. Postharvest losses varied according to market outlet. Postharvest losses arising from physical damages were influenced by poor harvesting techniques, inappropriate selection and design of harvest containers with varying depths, rough handling during loading and unloading and transportation modes and distances from field to packinghouse or eventual market outlet. Physiological damages such as chilling injury symptoms dominated supermarket outlets with and without chain stores. At all market outlets indiscriminate use of modified atmosphere packaging at temperature extremes had deleterious effects on fruit quality. Pathological losses often originated from physical damages and exposure to chilling temperatures resulted in secondary infections. Inadequate pre-harvest disease management protocols also contributed to multiple infections and disease proliferation. Entomological damages incurred prior to harvest contributed to losses due to ineffective pest management and poor coordination of postharvest sorting and grading practices. Other socio-economic constraints such as lack of postharvest knowledge and skills, impediments to flow of information to system participants, absence of postharvest training programmes, poor infrastructure and lack of incentives made early prediction of damage difficult. Against this background experiments were conducted using various approaches to quality management including postharvest dip treatments, modified atmosphere packaging and temperature management. Accordingly, it was demonstrated that hot peppers treated with a combined dip consisting of sodium hypochlorite and calcium chloride and packaged in micro-perforated high density polyethylene bags (HDPE) stored best at 10°C after 25 days. Chilling injury damage of hot peppers in micro-perforated bags at 8°C was slower than in fruits in sealed HDPE bags or control fruits in paper bags.

Keywords: postharvest losses; chilling injury; sodium hypochlorite; modified atmosphere packaging; micro-perforated.

I. INTRODUCTION

Hot pepper is considered as a nontraditional crop, and is grown in the Caribbean region for the purpose of domestic consumption and export to regional and international markets (Wallace et. al. 2015). Globalization and trade liberalization have created both challenges and opportunities for hot pepper growers and traders in the Caribbean. However, removal of preferential access to European Union (EU) markets for several plantation crops such as banana and sugar cane resulted in increased competition and subsequent loss of market share to larger efficient producers (Felix et. al. 2010). However, the liberalization of trade also presented opportunities for the marketing of nontraditional crops. Hence, many countries including Trinidad and Tobago, Jamaica, Guyana, Belize and many islands of the Organization of Eastern Caribbean States (OECS) embarked on diversification programmes establishing among others a hot pepper industry as a replacement to plantation crops to supply fresh hot pepper to local, regional and extra regional markets. These countries have targeted hot pepper as a priority crop in their agricultural diversification programme and in some countries also as a potential product for farmers who have been displaced from the banana industry. The choice is based on the fact that internationally the industry has been growing and the production and trade from the Caribbean has been increasing. As a result, the private sector and public sector including development organizations have targeted the industry for further development. While the industry may be attractive in terms of prices and volume demand, almost all hot pepper producers and traders have been challenged to meet current market demands due to inconsistent quality, poor postharvest handling, inadequate storage, packaging and transportation. Unable to counteract postharvest logistical constraints in a timely manner has often resulted in postharvest losses reaching as much as 25-50% (Mohammed et. al. 2014). Steps to reduce this high level of postharvest losses are crucial for the growth and development of the hot pepper industry in the Caribbean.

Hot pepper is also ingredient in local cuisine and is marketed as fresh and processed products. However, hot pepper remains a crop of significant cultural and economic importance, and therefore its full potential to generate increased revenue need to be explored. Trinidad and Tobago Ministry of Food Production has identified hot pepper as one of its priority
commodity in the National Food Production Action Plan 2012-2015. With current production averaging 710 tonnes, expansion in production is expected to increase to 1800 tonnes (NFPPAP, 2012). Hampered by variable quality and quantity the hot pepper is being promoted by a range of initiatives. The Trinidad Moruga Scorpion variety currently occupies top spot as the 'hottest pepper on the planet'. And beyond food production, Caribbean capsaicin has great potential for making value added products, such as nutraceuticals (food product with health benefits) (Bridgemohan et. al. 2016). Recently established Caroni Green Ltd (CGL) in Trinidad exported more than US$100,000 in hot peppers to the United States in the last quarter of 2015 and is currently selling US$20,000 worth of the crop weekly at the company’s 30-acre farm. To accelerate revenue specific postharvest problems must be addressed. Shrivelling, poor external appearance, chilling injury, physical injuries are the main reasons for consumer rejection and salability of hot peppers exported by this company. The need for a suitably humid environment around the fruits is essential in order to control both moisture stress as well as spore germination and infection, which ultimately cause decay. Grierson (1966,1969) and Mohammed et. al. (2010) stored commodities in perforated film packages in an attempt to regulate relative humidity. While previous investigations have focused on the efficacy of postharvest dips such as calcium chloride (Sams et. al. 1993) and sodium hypochlorite (Crowe et. al. 2005) when used separately, the combined application of both treatments have not be reported when used with modified atmosphere packaging.

The investigations reported in this study are concerned with the measurement of postharvest losses of hot peppers in different market outlets in Trinidad and to determine the effects of various postharvest dips alone or combined on the quality and storage life of hot pepper in micro-perforated HDPE bags at 5°C and 10°C and 90-95% relative humidity. The objective of the investigations is to define conditions which would enhance quality of hot peppers during the marketing process.

II. MATERIALS AND METHODS

Survey method, protocol design, loss measurement procedure:

The postharvest handling system of fresh market hot peppers chosen for study in this research was located in Trinidad. The system included a highly diverse and complex number of producers and traders characterized by widely scattered production areas and fragmented marketing services. This structural variety, coupled with widely differing postharvest practices among participants in the system posed considerable challenges for this research project which attempted better to understand the whole system and its operation.

The postharvest handling practices and qualitative and quantitative loss data of hot pepper producers and traders were derived from a baseline survey designed by La Gra (1986) and modified by Wilson (1991). The survey instrument was composed of a 12-module questionnaire and targeted hot pepper farmers and or vendors who participated in selling produce at all market outlets in North, Central and South Trinidad including farmer’s or municipal markets, wholesale markets, supermarkets with and without chain stores, roadside markets, mobile markets and export markets (Toronto, Canada). Farmer’s market retailers and wholesalers were randomly selected from the updated list compiled by the National Agricultural Development Corporation (NAMDEVCO). While all wholesalers were from the wholesale markets at Macoya (North East) and Debe (South), farmers’ market retailers were selected at different municipal markets throughout the country. These included Port of Spain market (10), Tunapuna market (13), Chaguanaus market (10), Marabella market (10) and Penal market (11). Roadside market retailers (15) and mobile market retailers (8) operating on a full-time basis only, were selected for evaluation. Supermarket retailers were divided into those with chain stores (SWCS) and those without chain stores (SWNCS). Only supermarkets that were in operation over the last five years with refrigerated displays and a minimum output of 25 kg of hot pepper sales per week were selected. All supermarkets (22) in Trinidad satisfying these requirements were interviewed.

At each market outlet, every stage with potential for reduction of marketable quality and eventual manifestation of postharvest losses, from the field as in the case of a producer, or from procurement in the case of a trader to the point of consumer purchase, was selected for in-depth analysis. This approach referred to the ‘systems approach’ appeared to be that with the greatest potential for understanding of hot pepper fresh market handling system.

The flow of hot pepper from the point of harvest to consumption for producers and traders was documented by observing and recording the duration of each component of the system, the time taken for the produce to move from one component to the next including delays as well as measurable characteristics of the environment such as temperature, relative humidity and time of day. In addition, hand-on familiarization with the produce handling operations provided the framework for examining typical patterns of decision and action taken by participants within the system. Procedures associated with interviewee consent and confidentiality agreement were explained according to protocols devised by Corbaoui and Ngadi (2016).

The following components served as stages at which data on marketable quality and postharvest losses were measured: harvesting; transportation, loading and unloading; sorting and grading; transportation from field to packinghouse and from packinghouse to market outlet; storage conditions; packing and packaging and display and purchasing. Each sampling
consisted of three replications of 12 kg of hot peppers randomly selected, and representative of a market load. Hot peppers were packed in polypropylene feed-bags (15-20 kg maximum capacity).

Visual quality was evaluated according to the method described by Kader et. al. (2010) for individual fruit using a nine-point hedonic scale for the parameters indicating symptoms of deterioration and limits of marketability with 1 = extremely poor and not usable, 3 = poor, serious deterioration, limit of usability, 5 = fair, deterioration evident, but not serious, limit of marketability, 7 = good, minor symptoms of deterioration, not objectionable and 9 = excellent, essentially no symptoms of deterioration. Following this, each sample was examined for damage and classified into two broad categories: (a) marketable and (b) unmarketable, based on the severity of damage of each fruit. The unmarketable fruits were designated as the postharvest loss, weighed and the percentage loss calculated against the original weight of produce.

To determine the nature of damage in the unmarketable category, hot pepper fruit samples were further subdivided into three categories according to the nature of the damage apparent at that location, that is, physical, physiological and pathological and entomological. Physical damages included cuts, bruises, punctures, scratches, splits, shaves, abrasions, decapped pedicels and cracks. Physiological damages included moisture loss (wilting, shrinkage), heat stress, chilling injury and internal breakdown. Pathological and entomological damages included damages caused by fungi, bacteria, thrips, mites. Weights of each category of damage were recorded and percent postharvest loss calculated for each category. Total postharvest losses were obtained by summing the losses recorded at each stage in the postharvest handling system. Hot pepper samples were also taken to the UWI Postharvest laboratory to collect data on fruit dimensions, firmness and colour. Data taken on prevailing environmental conditions in all locations averaged 30-32°C and 50-60% relative humidity.

Management of the interviews varied from farmer to trader. While some were located with the assistance of the Agricultural Assistants in the county extension offices of the Ministries of Agriculture in each country, others were located by their addresses as they appeared in the list of registered farmers. In several occasions farmers were met by attending some of the Agricultural District Meetings. With traders, a combination of methods was used. Supermarket retailers were informed by a telephone call to alert them of the existence of the survey, potential objectives and uses. Interviews with wholesalers, public markets, mobile market and roadside market vendors were done at the actual location mostly without previous arrangements. Interviews almost always took place in the midst of the activity characteristic of postharvest operations. As such the interviewer was able to pose questions in the work environment and, in many cases, to actually witness the decision-making of the traders where and when it occurred. At specific points and locations, temperature and relative humidity (Fisher Scientific Digital Hygrometer-thermometer Model EAI) were determined and recorded in order to assess whether these characteristics of the environment were causally related to quality deterioration.

Postharvest experiments:

Two postharvest experiments were conducted. For experiment 1, samples of 10 fruits of the local yellow hot pepper cultivar were either sealed in 0.025 mm-thick high density polyethylene bags (HDPE) with an electric heat sealer or sealed-packaged in micro-perforated HDPE bags. Fruits were selected to ensure that pedicels were green in colour and 2.5-3.5 cm in length, turgid with no discolouration. Only undamaged fruits at the same stage of maturity and free from obvious symptoms of disease were used. Ambient temperature on the morning of harvest was 23-25°C and 75-80% relative humidity. For the micro-perforated bags, 10 holes, each 0.25 mm in diameter were made on upper and lower sides of each bag. Control fruits were stored in paper bags. Packages were stored at 5°C and 10°C and 90-95% relative humidity, in separate storage rooms (American Panel Thermogrid walk-in chill rooms equipped with a Copeland refrigeration system) and examined at 5, 10, 15, 15, 20 and 25 day intervals for quality, chilling injury and decay incidence according to methods previously described by Mohammed et. al. (2010).

For experiment 2 hot pepper fruits of the local yellow cultivar harvested at the same stage of maturity were subjected to postharvest dip treatments prior to packaging and storage. Postharvest dip treatments were prepared separately of sodium hypochlorite (NaOCl), calcium chloride (CaCl₂) and a combined dip made up of similar concentrations of sodium hypochlorite and calcium chloride. The NaOCl dip treatment was prepared by diluting 5 ml of 3.5 m/v Javel bleach in 1 litre of distilled water as described by Palou and Crisosto (2003). The CaCl₂ solution was prepared by dissolving 20 g of CaCl₂ in 1 litre of distilled water according to Lasekan (2006) and Matui et. al. (2011). Undipped samples were included as dry controls. Hot pepper fruits were dipped in separate plastic buckets (5 litre capacity) for each of the three dip treatments indicated above. Thereafter, samples from each dip were placed on paper towels and allowed to dry at ambient temperature of 26-27°C and 60-75% r.h. for 45 minutes. Samples consisting of 10 fruits of the various dip treatments either alone or combined were seal-packed in 0.025 mm micro-perforated HDPE bags and paper bags (control) and stored at 10°C and examined after 3, 6, 9, 12 and 15 day intervals for marketable quality, decay incidence, pedicel and calyx discoloration and firmness according to methods described by Mohammed et. al. (2010). A sample of fruits subjected to the combined NAOCl plus CaCl₂ treatment was replicated 3 times sealed packaged in micro-perforated HDPE bags and allowed to store for an additional 10 days, that is, up to 25 days at 10°C to determine the maximum marketable quality.
Experimental design and data analysis:
Both experiments consisted of completely randomized designs with factorial arrangement of variables including three replicates with each replicate made up of 10 fruits. Data collected was subjected to analysis of variance (ANOVA) using the general linear models procedure of the statistical analysis system (SAS, 2002). Multiple comparisons among treatment means were done using the protected Least Significant Difference (LSD) at P = 0.5.

III. RESULTS AND DISCUSSION
The dynamics of time, temperature and relative humidity varied among the seven market outlets when postharvest events were investigated between harvest and consumer purchase. These events lead to qualitative and quantitative losses as shown in Table 1. At each market outlet, the actual interaction of quality-determining factors leading to physical, physiological, pathological and entomological damages accounted for the above differences. The rates at which these losses progressed were influenced by seasonality of production, type of cultivar and poor quality produce entering the system, inadequacies of temperature and relative management, mixed storage systems resulting in elevated levels of volatiles, duration of marketing and unexpected delays, improper packaging and handling and inadequate application of postharvest treatments.

Air shipments of hot peppers from Trinidad to ethnic markets in Toronto Canada succumbed to the highest quality losses of 46.6% and to 28.2% quantitative or postharvest losses (Table 1). Understandably, this export market incurred the longest time between harvest and consumer purchase of 12-15 days at 28-30°C, 50-65% RH, inconsistent with optimum storage conditions of 7-8°C and 90-95% RH recommended by Mohammed (1986, 2006) and Bridgemohan et. al. (2016). Accordingly, hot peppers at the point of sale from such shipments displayed quality losses due to moisture stress as evidence by shriveling, dark coloured dried pedicels which were either decapped with or without split ends. The hollow nature of fruits created avenues for cracks, punctures and bruises originating from overhead weight of poorly designed one-ply cardboard cartons with inadequate stacking strength as highlighted in previous investigations reported by Mohammed et. al. (2010). Inadequate logistical procedures also hampered export marketing of hot peppers. Hot pepper exporters functioned at the center of two contrasting segments of the industry: the producer or wholesaler in domestic markets for procurement of produce, and the broker or importer at foreign markets for buying produce. The exporter was faced with constant demands from importer or broker with respect to a consistent supply of high quality fruits with specific varietal characteristics, while the local producer or wholesaler was often unreliable, insensitive to specific quality requirements of foreign compared to domestic markets and unwilling to honour contractual obligations. Confronted with these challenges the exporter was often faced with poor initial quality produce. Also, under adverse conditions of temperature and relative humidity, mixed shipments of incompatible commodities promoted accumulation of undesirable volatiles as measured in previous studies by Mohammed et. al. (2010).

The benefits of low temperature storage facilities at supermarkets were not realized based on the levels of qualitative and quantitative losses shown in Table 1. Although temperature and relative humidity were similar with supermarkets with or without chain stores, losses were generally lower with supermarkets with chain stores (SWCS) than their counterparts without chain stores (SWNCs) despite longer duration of the former compared to the latter. Losses were inevitable in both types of supermarkets because fruits were held at least 10-12°C higher and relative humidity 30-35% lower when compared to recommended conditions cited earlier. Nevertheless, SWCS did maintain superior quality and less losses over SWNCs for the following reasons:

i. SWCS were equipped with chill rooms (4-5°C, 50-60% RH) for temporary storage prior to display,
ii. More rapid rotation of fruits,
iii. Modified atmosphere of pre-packaged fruits displayed on refrigerated shelves,
iv. More effective logistical arrangements to foster improved sorting and grading practices,
v. Availability of ramps, conveyor belts, trolleys, lift-jacks, fork lifts and palletized loads.

Less than 25% of the facilities above were available to other market outlets identified in Table 1. Roadside market retailers used hanging displays, slanted counters and different designs of corrugated boxes. Mobile retailers used the rear tray of vehicles while those at farmers’ or wholesale markets used separate partitions to minimize damage. The level of training and education of produce managers at supermarkets and exporters and the degree of awareness necessary to understand and detect latent damage by roadside retailers was inadequate for the level of daily technical and tactical decision making for produce handling. Instead, their knowledge gained from training focused on methods of price adjustments, inventory management, ordering and personnel matters. Very little information on quality determination and the inability to link physical, physiological, pathological and entomological defects with pricing procedures suggested deficiencies in understanding the necessity for co-ordination of the different components of the postharvest handling system of hot peppers.

The lowest level of qualitative losses was at wholesale markets, perhaps due to the shorter duration of fruits from the field to the point of sale. However actual postharvest losses were the least for farmer’s markets (18.1%) followed by roadside markets (20.6%) and SWCS (20.7%). No consistent trends existed among market outlets relating the marketing interval, that is, time between harvest and...
consumer purchase to the extent of physical injuries. It was therefore essential to determine how quality control events were administered and monitored in relation to the rate and level of quality deterioration. These events were investigated in this study in terms of physical, physiological, pathological and entomological damages and the sources of such damages as identified in previous studies reported by Mohammed (2006).

Physical damages were influenced by harvesting methods, number of times fruits were handled, vehicle-loading practices during transportation, packing arrangement and container depths and packing heights. Physiological damages were mainly due to chilling and heat injury as well as premature ripening and senescence. Pathological and entomological damages were attributed to pre-harvest and postharvest stress factors on the initiation, multiplication and proliferation of pests and diseases.

Harvesting techniques influenced physical damage based on data presented in Figure 1. Hot peppers detached at the natural abscission or fracture line showed no damage. Cutting pedicels with a sharp stainless steel knife was more effective in lowering physical injuries than pulling or twisting fruits off the plant (Figure 1). These results were supported by other studies published by Bridgemohan et.al. (2016).

In Figure 2, the data showed a linear relationship between handling times and percentage physical damages. Here physical damage increased by 5.4% as the number of handling times increased by increments of ten.

Regressions for physical damage of hot pepper fruits against distances from farm to packinghouse and from the packinghouse to market are illustrated in Figures 3 and 4. Physical damage increased by 3.5% as distance between farm and packinghouse increased by 12 km (Figure 3). A similar effect was shown for travelling distance between packinghouse and market outlet (Figure 4). Here, physical damage increased at the rate of 1.9% for every 12 km increase in travel distance.

Since quality deterioration due to chilling injury dominated several of the supermarket outlets where low temperature facilities existed (SWCS), this parameter was singled out to show how quality prediction could be effected by using the data presented in Table 3. Data (Table 3) indicated that for every 5 days increase in storage duration at 5°C, the rate of chilling injury damage to hot peppers increased by 0.6%, 0.8% and 0.9% for fruits in HDPE micro-perforated bags, sealed HDPE bags and control paper bags respectively. Accordingly, chilling injury damage of hot peppers in micro-perforated HDPE bags at 5°C was slower than in fruits in sealed HDPE bags or control fruits in paper bags. Likewise, at 10°C, fruits in micro-perforated HDPE bags had a slower rate of damage than fruits in paper bags. Therefore, micro-perforated HDPE bags resulted in a significant delay (P< 0.05) in chilling injury damage compared to sealed bags. At 5°C, fruits kept in paper bags (control), showed earlier symptoms of CI and the severity of damage exceeded that of fruit in HDPE packages (Table 3). Thus pitting caused by epidermal cell collapse occurred and as chilling period was extended, the pits enlarged and the rate of discoloration of pedicels, calices and seeds increased. Upon prolonged storage, despite the alleviation of water stress imposed by the saturated micro-atmosphere in sealed HDPE packages, chilling injury and probably membrane integrity of fruits in these bags was affected more than those in micro-perforated HDPE bags. This result suggested that while sealing reduced CI initially, some other factors in the water saturated environment as discussed by Mohammed et. al. (2014) may have accounted for changes in membrane integrity, leading to lower chilling injury ratings (Table 3). At best, HDPE packaging treatments at 5°C only delayed chilling injury as seen in Table 3, with micro-perforated HDPE bags having an obvious advantage, which was, however, significantly different at P< 0.05 level compared to sealed bags.

Pathological and entomological damages on hot peppers depended on the interaction of pathogen, produce and environment over time in support of studies investigated by Faulkner and Robatzek (2012). The major pests and diseases were field related, but they were accentuated by poor handling techniques and inadequate storage similar to that described by (Kader et. al. 2010). Thus, the available data in this study suggested a pest and disease profile according to:

1. Pre-harvest factors relating to the incidence of Anthracnose, virus-induced damage due to thrips, white fly and and mite attacks;
2. Poor handling resulting in the incidence of secondary infections due to bacterial soft rots (Erwinia spp.) and fungal infections (Fusarium spp.); and
3. Secondary infections arising from adverse storage or field conditions where both upper and lower limits temperature were exceeded, e.g. chilling injury below 8-10°C and heat injury above 35°C.

It was also demonstrated that postharvest dip treatments functioned differently to curtail diseases mentioned above when hot peppers were packaged in micro-perforated HDPE bags at 10°C. Regression analysis of data (Table 4) showed that the rate of decay was significantly higher over time for fruits with no dips than sodium hypochlorite or calcium chloride treated fruits. Hot pepper fruits not subjected to a dip treatment prior to packaging and subsequent storage at 10°C, were rated above 3.0 and were therefore unsalable after 9 days, whereas fruits treated alone either with calcium chloride or sodium hypochlorite were similarly rated after 12 and 15 days respectively. Noteworthy, was the efficacy of the combined calcium chloride plus sodium hypochlorite treatment which had a decay rating of 1.6, representing 100% marketable fruits after 15 days when packaged in micro-perforated HDPE bags at 10°C (Table 4). Accordingly, the combined dip treatment conferred an additive effect in
suppressing decay not evident with the other treatments. The sodium hypochlorite component of the combined dip treatment did not only eliminate most of the surface pathogens but was more effective against those microorganisms which were embedded in the fruit tissue or located in natural openings such as stomata and lenticels as reported by Crowe et al. (2005), Mutui et al. (2011), Kitinoja (2001). The bactericide, sodium hypochlorite supplemented with calcium chloride probably penetrated the fruit tissues slowly preventing the disintegration of fruit tissue, thereby further limiting the release of substrates for pathogen proliferation. In other studies, McGuire and Kelman (1982), found increased resistance to bacterial soft rot in potato tubers and correlated this to an increase in calcium content. Elsewhere, Ferguson and Drobak (1988), Joyce et al. (1997) discussed the importance of calcium ions both in protection from pathogens and in reducing the rate of fruit ripening and senescence. They also concluded that calcium reduced or delayed cell wall breakdown resulting in a subsequent delay in softening. The assumption from these studies was that an increase in calcium levels in the presence of a bactericide such as sodium hypochlorite could result in increased resistance to degradation of pectate substrates in the middle lamella and cell wall. Because many postharvest decay microorganisms utilize peptic enzymes as their primary weapon of attack, changes in calcium metabolism are likely to be involved in alteration of susceptibility of plant tissue degradation by such pathogens. This activity seems to be enhanced when used with a bactericide. This 15-day marketing period is adequate for local marketing and is particularly advantageous to producers and traders involved in air-freight export. However, increasing air-freight rates and absence of infrastructure to facilitate perishable handling coupled with the lack of suitably trained airfreight cargo handlers, sensitive to the handling requirements of perishables, suggest that alternative modes of overseas transport such as sea-freight should be explored. In order to accommodate the longer time involved in such alternative further extension of storage life would be needed. Thus, the combined postharvest dip treatment applied to hot peppers prepackaged in micro-perforated HDPE bags at 10°C which gave a shelf life of 25 days would therefore be useful for hot pepper exporters opting to use the less expensive mode of sea transport.

REFERENCES


Figure 1. Percentage physical damages as influenced by number of times hot pepper fruits were handled.

Figure 2. Percentage physical damages of hot peppers as influenced by travel distance (km) between packinghouse and retail market.

Figure 3. Percentage physical damages of hot peppers as influenced by travel distance (km) between farm gate and packinghouse.
Table 1. Influence of time and events between harvest to consumer purchase on qualitative and quantitative losses of hot peppers due to physical damages.

<table>
<thead>
<tr>
<th>Types of markets</th>
<th>Physical damages from harvest to consumer purchase</th>
<th>Qualitative losses (%)</th>
<th>Quantitative losses (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmers’</td>
<td>Temp. /RH 1-2 days at 28-30°C, 60-75% RH</td>
<td>33.3</td>
<td>18.1</td>
</tr>
<tr>
<td>Roadside</td>
<td>Temp. /RH 4-7 days at 28-32°C, 60-75% RH</td>
<td>42.2</td>
<td>20.6</td>
</tr>
<tr>
<td>Mobile</td>
<td>Temp. /RH 4-7 days at 28-32°C, 60-75% RH</td>
<td>44.4</td>
<td>28.9</td>
</tr>
<tr>
<td>Supermarket with chain store</td>
<td>Temp. /RH 5-6 days at 20-22°C, 50-70% RH</td>
<td>28.2</td>
<td>20.7</td>
</tr>
<tr>
<td>Supermarket without chain store</td>
<td>Temp. /RH 3-4 days at 20-22°C, 50-70% RH</td>
<td>36.6</td>
<td>29.4</td>
</tr>
<tr>
<td>Wholesale</td>
<td>Temp. /RH 1 day at 28-30°C, 60-75% RH</td>
<td>7.3</td>
<td>28.3</td>
</tr>
<tr>
<td>Export</td>
<td>Temp. /RH 12-15 days at 28-30°C, 50-70% RH</td>
<td>46.6</td>
<td>28.2</td>
</tr>
</tbody>
</table>
Table 2. Physical damages of different layers of hot peppers as influenced by drop heights.

<table>
<thead>
<tr>
<th>Fruit layer</th>
<th>Physical damages (%)</th>
<th>Drop heights (cm)</th>
<th>Regression equations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top layer</td>
<td></td>
<td>10</td>
<td>2.0a 2.7ab 3.6cd 5.0e</td>
</tr>
<tr>
<td>Middle layer</td>
<td></td>
<td>20</td>
<td>3.0bc 4.0d 7.5g 9.6h</td>
</tr>
<tr>
<td>Bottom layer</td>
<td></td>
<td>30</td>
<td>3.5cd 6.4f 11.0i 14.5j</td>
</tr>
</tbody>
</table>

Table 3. Chilling injury damage of hot peppers stored up to 25 days at 5°C and 10°C.

<table>
<thead>
<tr>
<th>Temperature/ Package</th>
<th>Chilling injury Z</th>
<th>Regression equations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 days</td>
<td>10 days</td>
</tr>
<tr>
<td>HDPE sealed</td>
<td>1.0a 1.0a 1.2ab 1.5bcd 2.5ghi</td>
<td>y = 4.01 + 0.16x, R² = 0.81</td>
</tr>
<tr>
<td>HDPE m/perforated</td>
<td>1.0a 1.4ab 1.5bcd 1.7cde 1.8de</td>
<td>y = 3.86 + 0.12x, R² = 0.87</td>
</tr>
<tr>
<td>Control</td>
<td>1.2ab 1.6bcd 2.0ef 2.8i 4.0j</td>
<td>y = 4.25 + 0.17x, R² = 0.89</td>
</tr>
<tr>
<td>At 5°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HDPE sealed</td>
<td>1.1ab 1.2ab 1.5bcd 2.0ef 2.3fg</td>
<td>y = 1.32 + 0.10x, R² = 0.84</td>
</tr>
<tr>
<td>HDPE m/perforated</td>
<td>1.1ab 1.1ab 1.2ab 1.8de 1.0a</td>
<td>y = 1.10 + 0.08x, R² = 0.90</td>
</tr>
<tr>
<td>Control</td>
<td>1.2ab 1.3ab 1.7cde 2.3fg 2.7hi</td>
<td>y = 1.62 + 0.12x, R² = 0.92</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>At 10°C</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Z Chilling injury index 1-4: 1 = none, 2 = slight, 3 = moderate, 4 = severe.

Table 4. Effect of postharvest dip treatments upon incidence of decay on hot peppers stored in micro-perforated HDPE bags at 10°C up to 15 days.

<table>
<thead>
<tr>
<th>Postharvest dip treatments</th>
<th>Decay rating at 10°C (days) Y</th>
<th>Regression equations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Control</td>
<td>1.0a 1.9bcd 3.1ef 3.5f 4.7g</td>
<td>y = 0.57 + 0.43x, R² = 0.78</td>
</tr>
<tr>
<td>CaCl₂</td>
<td>1.0a 1.0a 2.3cd 3.1ef 3.5f</td>
<td>y = 0.32 + 0.18x, R² = 0.84</td>
</tr>
<tr>
<td>NaOCl</td>
<td>1.0a 1.0a 1.2ab 2.1bcd 3.1ef</td>
<td>y = 0.24 + 0.09x, R² = 0.82</td>
</tr>
<tr>
<td>CaCl₂ + NaOCl</td>
<td>1.0a 1.0a 1.0a 1.2ab 1.6abc</td>
<td>y = 0.11 + 0.17x, R² = 0.80</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>0.80</td>
<td></td>
</tr>
</tbody>
</table>

Y Decay rating 1-5: 1 = none, 2 = slight, 3 = moderate (limit to salability), 4 = severe, 5 = completely decayed.