Development of Effective Tomato Package for Post-Harvest Preservation

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Abstract - *This study evaluated the effects of chemical content on packaged materials on fresh tomato. The study was carried out by using kraft paperboard to design a package with different numbers of holes, back cover of polyethylene and some without holes. The packages were designed to contain about twenty five pieces of average sized tomatoes on one row arrangement. The packages consist of six packages and a control without packaging named M, N, O, P, Q, R and S respectively. These packages were distinguished with some having varied number of holes, covered with polyethylene and a control without hole nor covering. Tomatoes (Solanum Lycopersicum) were packaged in these packages for sixteen days to ascertain their physiological weight loss, percentage of decay, chemical interaction with the packaging materials and overall shelf life for each package, reading was taken at intervals of four days. The data obtained were analyzed using analysis of variance and means of different parameters were compared by least significant difference (LSD). The result revealed that packaging had a significant effect on physiological weight loss, percentage of decay, chemical interaction of the packaging material and overall shelf life. The least physiological weight loss of 0.00% was recorded on package N for the fourth day and the highest physiological weight loss of 22.22% on package S on the sixteenth day. For the first four days, none of the tomatoes decayed in all the packages but on the sixteenth day, package N had the least percentage decay of 8.00% with package P having the highest percentage of decay of 53.85%. The interaction of the chemical content of the tomato and the packaging material to the rate of decay showed that there is significant difference between the interactions ($P \leq 0.05$). The following elements – Aluminum, Arsenic, Lead, Cadmium, Silicon and Tin – present in the packaging material proved to be poisonous when tomatoes decayed in the packaging material. The shelf life of 20 days was observed in package N while other packages had 15 days. It can be concluded that packaging of fresh tomato with kraft paperboard of eight holes of 35mm each resulted in longer shelf life and least rate of decay.*

Key Words: Fresh, tomato, Packaging, Physiological, weight, shelf-life.

1. INTRODUCTION

The shelf life of a fresh tomato is the duration from harvesting a matured tomato to a day before spoiling. Temperature is a very important factor that affects the shelf life of a tomato. At a temperature of 5^0C, tomato respire moderately between 10 – 20 $MgC0_2$/Kg – hr while at a temperature of 7^0C tomato can have a shelf life of up to three weeks (21 days) (Package India, 1998). In the study of Dario et al, (2018) on the chemistry behind tomato quality, they confirmed that tomato contains volatile and non – volatile chemical substances. Some of them include: ethers, aldehydes, ketones, fatty acid derivatives, amino acid derivatives, terpenoids, sugars, umami compounds, carotenoids and polyphenols. These chemicals in tomato can react with other chemicals used to extend the shelf life of tomato or chemical contents of tomato packages. In the study of Gherezi et al (2012) and Anyasi et al (2016) to extend the shelf life of tomato with chemicals, they succeeded without testing the effects of those chemicals they used. Some of the chemicals they used are boric acid (H_3BO_3), calcium chloride ($CaCl_2$), and potassium tetra Oxo-manganese ($KMnO_4$).

In Nigeria, tomato is cultivated in many parts of the country. It thrives well in Savanna agro-channel zone with less pest and diseases of tomato. Major producing areas lies between latitude 7.5^0N and 13^0N and within a temperature range of 25^0C – 34^0C. The states in this categories are Jigawa, Kastina, Zamfra, Sokoto, Kaduna, Bauchi, Gombo, Taraba, and Kano in the northern part of the country. It can also be grown in southern states like Delta, Kwara and Oyo (Agronews, 2016). Tomato is a vegetable with high content of water which makes it to have a very short shelf life when exposed to high temperature. In its season, it is produced in abundance which needs to be kept fresh for consumption. To do this, packaging of fresh tomato is one of the best option.

According to (Raheem, 2012), packaging material could be either rigid or flexible. Rigid packaging materials are not easily moved out of their position. Some examples include glass, plastics, jars, cans pottery, wooden boxes, drums, tins and tubes. Flexible packaging is a major group of materials that include plastic films, paper foil, vegetable fibres, cloths, sacks and sealed or unsealed bags. The development of packaging shows a growth from crude methods to sophisticated, advanced and appealing methods with future prospects of better ways. A study of the history shows that earlier packages started from leaves, hollowed out tree limbs, grounds, skins, baskets and earth ware. The development of packages moved according to the following trends: ceramics, glass, paper (Oldest flexible packaging), iron, plastics, cellophane and recently modified atmosphere packaging (MAP), active packaging, smart or intelligent packaging, biodegradable packaging and application of Nano composite (Raheem, 2012; Scater, 2010). The use of any package to extend the shelf life of tomato can be harmful when the package contains harmful chemicals.

1.1 Related Literature

Shelf life of fruits is a major determinant for their usefulness with time post-harvest. The said shelf life is the post-harvest period within which such fruits are good for consumption without any adverse effects to the health of consumers as well as its usefulness to agro based industries. It remains one of the cardinal means of determining the viability of the usefulness of any fruit post-harvest. One of the means of being in control of shelf life is by adopting a reliable packaging. The packaging of fruits have been developing progressively as the years go by. In recent discoveries, intelligent packaging and modified atmospheric packaging (MAP) have been of great breakthrough in extending shelf life of fruits. The shelf life of fruits and vegetables can be extended with greater gain to the economy and improved health for Nigerians. According to executive secretary of agricultural fresh produce and exporter association of Nigeria (AFPGEAN) Akin Sawyer says between 55-72 percent of fresh produce grown in the country perish before they can be consumed . He added that Nigeria had about five times more arable land than Kenya but Kenya earned about a billion dollars in fresh produce export but Nigeria struggled to earn ten million dollars annually.

The basic principles of tomatoes (Solanum Lycopersicum) biology and chemistry are of great importance in determining a suitable package that can extend its shelf life. The chemistry of tomatoes according to (Dairio et al, 2018) shows that it has some basic chemical components such as:

- Flavour
- Fatty acid derivatives
- Amino acid derivatives
- Terpenoids
- Sugers
- Organic acids
- Umami compounds
- Steroidal glycoalkaloids and
- Polyphenoils.

Similarly, in the biology of tomatoes post-harvest, it is a living tissue. It has high respiration rate and other metabolic processes before maturation and ripening throughout its marketing cycle. The respiration of fresh fruits and vegetables together with the prevailing temperature are common and most factors that affect shelf life. Higher respiration releases higher heat and energy. Respiration itself is a catabolic process of using atmospheric oxygen of carbohydrates, fats, proteins and organic acids in the plant tissue to form intermediate compounds and eventually CO2, water and metabolic energy (Alejandra et al, 2009). In the process of short supply of oxygen, production of small alcohol will occur giving rise to off flavor, off odour and finally decay and spoilage (Packaging for fresh fruits and vegetables, retrieved January, 2019). According toShukadev and Tridih,(2009), some respiratory quotients of some substances in fresh fruits are as follows:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O \qquad (1)$$

Glucose RQ = 1

$$C_4H_6O_5 + 3O_2 \longrightarrow 4CO_2 + 6H2O \qquad (2)$$

Malic Acid RQ = 1.33

$$C_{18}H_{36}O_2 + 26O_2 \longrightarrow 18CO_2 + 18H_2O \qquad (3)$$

Stearic Acid RQ = 0.7

Paper is a very good packaging material for tomato but in the manufacture of paper and board, some chemicals are added to improve the needed properties. The basic element – cellulose fibre – used in paper production are mixed with enough water and little chemical additives. Most of the additives are lost when the water are being removed. The truth remains that some of these chemicals that are retained in the paper and board after manufacture can migrate into food if it is used in packaging. These chemicals if migrated into food can endanger human health, change food composition as well as bring about quick deterioration of the food.

According to (Summerfield and Cooper, 2000), chemical migration is a diffusion processes that is subject to both kinetic and thermodynamic control. The diffusion process is influenced by:

1.1.1 Temperature: Migration increases with increase temperature of contact.

1.1.2 Time: Migration is higher for contact in long duration.

1.1.3. Thickness of material: The higher the thickness, the lesser the migration.

1.1.4 Nature of material and amount of migrant in the material: Migration decreases with substance of higher molecular weight in the packaging material.

1.1.5 Type of food: The softness or hardness of the surface of food affects the migration of chemical additives.

The chemical additives are in the following categories:

i. Functional additives.

ii. Process chemicals or processing aids.

iii. Intermediate group of chemicals.

These chemicals can be soluble or readily dispersible in water which greatly affects tomato when paper that contains harmful chemicals are used to package it.

2. Materials and Methods

2.1 Description of study area:

The study was conducted at the Chemical Engineering Laboratory of Federal Polytechnic Nekede, Imo State, Nigeria. Nekede is located 5.41870N, 7.0753^{0}E in Owerri West local government area of the state. It is eight (8) Km from Owerri capital city of Imo state. The study was conducted in April, 2022. The average temperature and humidity of Nekede at that period is 30^{0}C and 73.5% respectively during the experimentation time.

2.2 Experimental Materials and Design

The tomatoes were bought from Relief market in Owerri six days after it was harvested and transported from Jos in Plateau state in Nigeria to Owerri in Imo state. The tomato fruits selected were those without defect. The determination of volumes of some of the tomatoes helped in designing a package with Kraft paperboard that can contain an average of twenty five (25) tomatoes. Six different packages of Kraft paperboard were used and the seventh one as control without package. These packages are: Package with four holes of 35mm each, Package with eight holes of 35mm each, Package with four holes of 35mm and back cover of polyethylene, package with eight holes of 35mm and back cover of polyethylene, Package without holes, Package without holes with back cover of polyethylene and control without package. These packages were named M, N, O, P, Q, R, and S. The number of tomatoes in these packages ranges between 15 and 28 which were packaged without the use of any chemical additive in the packaging. The package was designed to contain one layer of the tomatoes without any one on top of each other. The average time for collecting data during the experimentation was between 8.30am to 9.30am. The temperature, humidity, weight and number of decay were daily determined from each package.

2.3 Sample preparation

The tomatoes without decay were selected and washed with clean water. It was kept to dry before packaging.

2.4 Methods of analysis

The temperature, humidity, physiological weight loss, chemical content of tomato and package were collected during the experimental period on the six packages and the control. The collected data were used to determine the shelf life of the tomatoes in each package. The data were taken from the packages during the packaging period before the shelf life was exceeded as follows:

2.5 Chemical effect

The chemical contents of tomatoes, Kraft paper and decayed tomatoes on the Kraft paper were determined and analyzed. According to Ali et. al (2020), all mineral contents are grouped into major elements, trace elements and ultra-trace elements. In their findings, major elements are needed daily above 50 milligrams, trace elements are needed bellow 50 milligrams while ultra – trace elements are needed about 1 micrograms daily.

2.6 Percentage of physiological weight loss

The physiological weight loss is one of the tool used to determine the shelf life of fruits like tomato. The weight loss was determined by using the method described by Ghareezi et al (2012), Zewdie (2017) and Ashenafi (2018).

$$\text{PPWL } (\%) = \frac{W_O - W_t}{W_o} \times 100 \tag{4}$$

Where

PPWL (%) = Percentage physiological weight loss.

Wo = Weight of tomatoes at day 0.

Wt = Weight of tomatoes after storage for a determined number of days.

2.7 Shelf life

The shelf life of tomato is a period of time which starts from harvest and extends to the beginning **of** the decay of tomato.

2.8 Percentage of decay

Percentage of decayed tomatoes is the ratio of decayed tomatoes at a particular day to the total initial number of tomatoes. According to Mama et al (2026)

$$\% \text{ of decay} = \frac{\text{Number of decayed tomatoes}}{\text{Total initial number in the package}} \times \frac{100}{1} \tag{5}$$

2.9 Statistical Analysis

The data obtained was statistically analyzed for analysis of mean, standard deviation and variance. The mean separation was based on least significant difference (LSD) at 5% level of significant.

2.10 Percentage of physiological weight loss

Table 1: Percentage of physiological weight loss from 4th to 16th day.

Packaging material	Storage period in days			
	4	8	12	16
M	3.33	6.67	10.00	13.33
N	0.00	7.14	10.71	14.29
O	3.33	6.67	16.67	16.67
P	6.67	10.00	13.33	13.33
Q	3.33	6.67	10.00	13.33
R	3.23	3.23	5.16	6.45
S	5.56	11.11	16.67	22.22

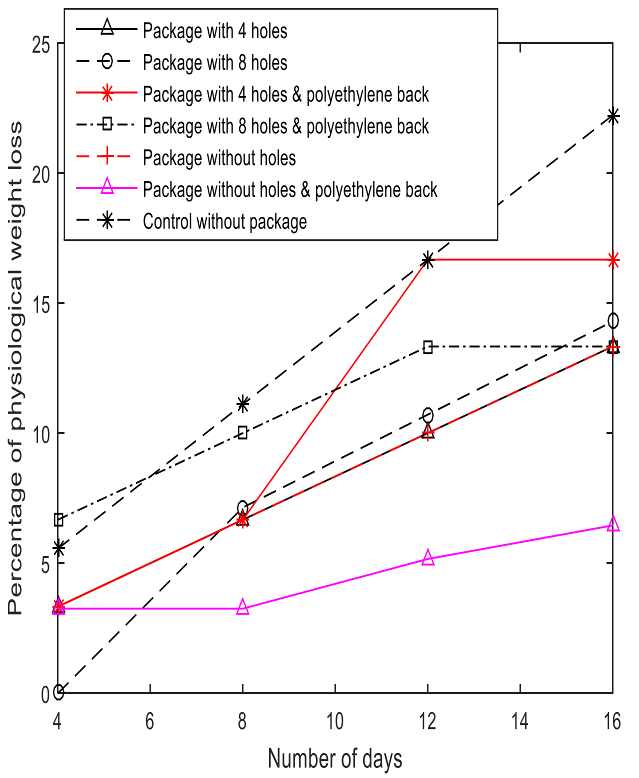

Fig. 1: Graph of rate of physiological weight loss from 4th to 16th day

The type of package, number of holes and cover of polyethylene on packages affected the physiological weight loss of tomatoes. In the first four days of the experiment, package with four holes, package with four holes with back cover of polyethylene, package without holes, package without holes with back cover of polyethylene and control without packaging had 3.33%, 3.33%, 3.33% and 3.23% respectively as their physiological weight loss. Furthermore, package with eight holes had no physiological weight loss while package with eight holes and back cover of polyethylene had 6.67%. The above result is similar to the work of Abra et.al (2016) where higher physiological weight loss was noticed on packages at ambient temperatures as compared with packages in refrigerator. From Table 1, the physiological weight loss continues to vary with days in all the packages. Finally on the sixteenth day, package with four holes, package with eight holes and back cover of polyethylene and package without holes had 13.33% physiological weight loss with the control without packaging having the highest physiological weight loss of 22.22% and package without holes and back cover of polyethylene having the least physiological weight loss of 6.45%. The result shows that the kraft paperboard covered with polyethylene maintained a controlled heat and air as there were no holes on it. On the other hand, the control without package was exposed to the environmental heat and air flow without control.

2.11 Percentage of decay

Table 2: Percentage of decay of tomato from 4th to 16th day.

Packaging material	Storage period in days			
	4	8	12	16
M	0.00	0.00	26.09	30.44
N	0.00	0.00	0.00	8.00
O	0.00	12.50	29.17	50.00
P	0.00	19.23	19.23	53.85
Q	0.00	12.50	29.17	41.67
R	0.00	7.14	21.43	28.58
S	0.00	6.67	6.67	33.33

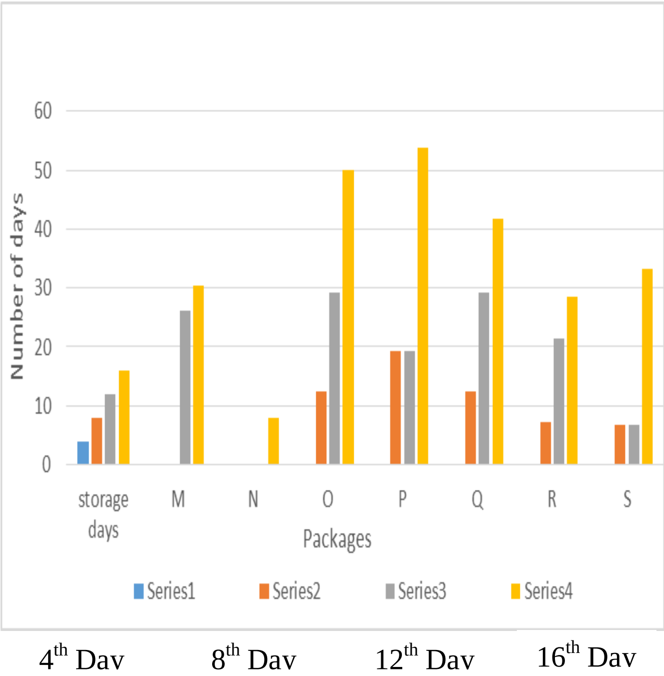

Fig. 2: Bar chart of comparison of tomato decay from 4th to 16th day

Table 2 and Fig. 2 shows that decay of tomatoes started in some of the packages on day eight of the packaging. This could be due to the humidity of the room having the highest humidity of 91.00% within the period of experimentation. The different packages showed different percentages of decay. Package with eight holes started to decay on the sixteenth day with the least percentage decay of 8.00%. On the sixteenth day, package with eight holes and back cover of polyethylene had the highest percentage decay of 53.85%. The decay percentages of other packages are as follows: Package with four holes (30.44%), Package with eight holes (50.00%), Package without holes (41.67%), Package without holes and back cover of polyethylene (28.57%) and control without packaging (33.33%). The result shows that packages that had the highest temperature also showed high percentage of decay. The presence of high temperature also leads to the onset of irreversible rise in respiration and the production of ethylene (Shukadev and Tridib, 2009). The high moisture content generated by high temperature leads to tomato decay (Gherezi et .al, 2012).

According to Zewdie (2017), decay of tomatoes are noticed as bruises. In his work tomatoes packaged in an enclosure had higher number of bruised tomatoes than those packaged in open containers. This result summarily validates that high temperature of packages can easily lead to high rate of decay of tomatoes.

2.12 Shelf life

The shelf life of tomatoes is the day preceding excessive weight loss and beginning of decay. From collected data, excessive weight loss was noticed on the tenth (10th) day and the shelf life of tomatoes packaged in all the packages were on the ninth (9th) day but for N package (Package with 8 holes) it was on the fifteenth (15th) day. The tomatoes used in the package were transported from Jos to Owerri after six days from the day of harvest. Invariably, six days was added to the realized shelf life in Owerri.

Table 3: Shelf life of tomatoes in different packages

Packages	Shelf Life (Days)
M – Package with four holes	15
N – Package with eight hole	20
O – Package with four holes and back cover of polyethylene	15
P – Package with eight holes and back cover of polyethylene	15
Q – Package without holes	15
R - Package without holes and back cover of polyethylene	15
S – Control without package	15

2.13 Effect of chemical

The fresh tomato is made up of some chemical element as well as the kraft paperboard used for packaging. The interaction of chemical content of the tomatoes and the packaging material to the rate of decay showed that there is significant difference between the interactions ($P \leq 0.05$). The actualized P value is 0.0153 but the P value for the rate of decay based on the chemical content of tomato is 0.1143. This implies that ($P \geq 0.05$) showing no significant difference. The result confirmed that the chemical content of tomato alone does not determine the rate of decay. The use of $CaCl_2$ and acetic acid had proved significant difference in the rate of decay of tomato in agreement with the present work (Gherezi et. al, 2012).

According to Ali et. al (2020), all the mineral elements are grouped into major elements, trace elements and ultra-trace elements. In their findings major elements are needed daily above 50 milligrams, trace elements are needed bellow 50 milligrams daily while ultra-trace elements are needed about 1 microgram daily.

Table 4 shows these groupings, their quantity in the decayed tomatoes in the kraft paperboard and effect on human health.

Table 4: Effect of mineral element on decayed tomato to human health

S/N	Element	Quantity in decayed tomato	Effect on human health
	Major elements		
1	Potassium	7.899ppm (7.899mg)	Not harmful to human health <50mg
2	Calcium	3.988ppm (3.988mg)	Not harmful to human health <50mg
3	Magnesium	0.022ppm (0.022mg)	Not harmful to human health <50mg
	Trace elements		
1	Iron	0.136ppm (0.136mg)	Not harmful to human health <50mg
2	Zinc	0.212ppm (0.212mg)	Not harmful to human health <50mg
3	Copper	0.010ppm (0.010mg)	Not harmful to human health <50mg
4	Manganese	0.387ppm (0.387mg)	Not harmful to human health <50mg
5	Chromium	0.024ppm (0.024mg)	Not harmful to human health <50mg
6	Nickel	0.032ppm (0.032mg)	Not harmful to human health <50mg
7	Molybdenum	0.228ppm (0.228mg)	Not harmful to human health <50mg
	Ultra-trace element		
1	Aluminum	10.839ppm (10,839µg)	Very greatly unhealthy > 1 µg
2	Arsenic	0.072ppm (72µg)	Greatly unhealthy to human > 1 µg
3	Lead	0.100ppm (100µg)	Greatly unhealthy to human > 1 µg
4	Cadmium	0.047ppm (47µg)	Greatly unhealthy to human > 1 µg
5	Silicon	0.894ppm (894µg)	Very greatly unhealthy > 1 µg
6	Tin	0.045ppm (45µg)	Greatly unhealthy to human > 1 µg

3. Conclusion

Packaging had a significant effect on physiological weight loss, decay percentage, chemical interaction and overall shelf life of fresh tomato. Based on the result of this study, it can be concluded that packaging of fresh tomato with kraft paperboard with eight holes of 35mm each resulted in longer shelf life and least rate of decay.

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