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Studies on Thermal, Textural and Quality Parameters of Multiplier CO 4 Onion Bulb (*Allium cepa* L.var *aggregatum* Don.)

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Thermal properties are essential for predicting the temperature distribution within the foods and to allow optimum design of heat transfer equipment. Study of thermal, textural properties and quality parameters are necessary to understand the behavior of onion during storage and consumption. All these properties were measured and a data base for the CO 4 variety was formed. Thermal properties of the fresh and three months stored onion bulbs were estimated. The specific heat, thermal conductivity and volumetric heat capacity were linearly related and also the thermal diffusivity indirectly related with moisture content of the fresh and three months stored onion. Penetration load and crushing load of fresh and stored onion bulbs were determined. The mean values of total soluble solids (TSS), colour parameter 'a' and pyruvic acid content were 16.91±0.90 to 17.29 ± 0.62 per cent, 15.23 ± 10 to 14.58±0.67 and 4.58±0.41 and 4.25±0.39 µmol/g respectively, for the fresh and three months stored onion.

All the properties were assessed at an average moisture content of 83.45±1.10 per cent (wb) for the fresh onion bulbs and 81.82±1.01 per cent (wb) for the three months stored onion CO 4 variety.

Key words: Specific heat, Thermal conductivity, Thermal diffusivity, Volumetric heat capacity, Penetration load and Colour.

Knowledge about the thermal properties such as specific heat, thermal conductivity, thermal diffusivity and volumetric heat capacity are essential for prediction of process time and temperature for foods. It is also equally important to preserve the viability, nutrients and quality of the material (Singal and Samuel, 2003).

Textural properties like penetration load and crushing load of the agricultural materials correlates with the deformation due to forces applied on the materials. The crushing strength is required for the design and development of the grading and handling systems. (Chandrasekar and Viswanathan ,1999).

Moisture content is one of the determining factors which decides the market value of the stored onion bulbs. Likewise total soluble solids colour and pyruvic acid content parameters also derive a better market value for some of the agricultural commodities.Since CO 4 onion has high productivity and demand in Tamil Nadu it had taken for storage studies.

Materials and Methods

Storage studies were conducted at the Food and agricultural process Engineering, Tamil Nadu Agricultural University, Coimbatore.

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Thermal properties

Specific heat capacity, thermal conductivity, thermal diffusivity, and volumetric heat capacity are important properties of a material related to heat transfer characteristics. These parameters are essential in heating, drying and cooling processes of stored onion bulbs.

Specific heat

The method of mixtures was followed to determine the specific heat of onion bulbs by equating the heat lost by the hot sample in water to the heat gained by the water and the calorimeter from the hot sample. A calorimeter made up of copper fitted with a stirrer was used in this study. The calorimeter was closed with a Bakelite lid having a provision to insert a thermocouple with digital display. The weight of the empty calorimeter was recorded along with stirrer and 3/4th volume of water filled. The initial temperature of the water (T_i) in the calorimeter was also recorded. Then, the steam heater with water was heated. The known weight of the sliced fresh onion bulb was taken. The samples were heated and the temperature was recorded periodically till it reached to a temperature of 60-80°C. Then, the heated samples (T_s) were transferred quickly to the calorimeter filled with cold water and closed immediately. The mixture was stirred well until it attains an equilibrium temperature

(T_f). The specific heat of onion bulb was calculated using the following formula.

$$C_p = \frac{(W_{CW} - W_C)C_{PW}(T_f - T_i) + w_C S_C(T_f - T_i)}{(W_{CWO} - W_{CW})\,(T_s - T_f)}$$

where,

C_P - Specific heat of onion bulb, kJ/Kg °K

W_C - Mass of the empty calorimeter and stirrer, Kg

W_{CW} - Mass of the empty calorimeter, stirrer and cold water, Kg

W_{CWO} - Mass of the empty calorimeter, stirrer, cold water and onion bulb, Kg

S_C - Specific heat of calorimeter, kJ/Kg °K

C_{PW} - Specific heat of water, kJ/Kg °K

T_i - Initial temperature of calorimeter, stirrer and cold water, °K

T_S - Temperature of hot onion bulb sample, °K

T_f - Final temperature of calorimeter, stirrer, cold water and onion bulb, °K

Thermal conductivity

Thermal conductivity was determined by the line heat source transient heat flow method. The apparatus consisted of a thermal conductivity probe fixed at the middle of the test cylinder, DC power supply unit and instrumentation for the measurement of current and temperature. The heating probe was made of a brass tube provided with 26 standard wire gauge thick constantan heating wire of resistivity 10Ù/m. Two copper-constantan thermocouple junctions were used to measure the temperature. The thermal conductivity was calculated from the measurement of the rise in temperature with time. (Chandrasekar and Viswanathan, 1999).

Fresh onion bulbs and three months stored were filled in the cylinder and heated. The initial temperature and increase in temperature at 60 and 30 seconds interval were noted for 25 - 40 minutes from the moment of switching on the power supply. From the rise in temperature with respect to time, the time correction factor 20 was determined. A plot of rise in temperature (“T) as shown by the thermocouple versus heating time‘è’ and a plot of dè/dT versus time (t) were drawn. The time correction factor $è_o$, was obtained by extrapolating the resulting straight line portion of the dè/dT versus average time (t) graph. The thermal conductivity values were calculated using the following equation.

$$K = \frac{Q}{4\Pi\, T_2 - T_1} \ln \frac{\theta_2 - \theta_1}{\theta_1 - \theta_0}$$

where,

K - Thermal conductivity of onion bulb, W m_{-1} K_{-1}

Q - Heat supplied (I_2R), W m_{-1},

R - Resistivity of the heating probe, Ohm/m,

I - Current, Amperes,

$è_1$ and $è_2$ - time corresponding to temperatures T_1 and T_2, S

$è_0$ - time correction factor corresponding to T_0, S

Thermal diffusivity

The thermal diffusivity of the fresh and three months stored onion bulbs was calculated from the values of the thermal conductivity K, specific heat Cp and their corresponding bulk density (ñb) using the following relationship (Plange *et al*., 2012).

$$\alpha = \frac{Kc}{\rho b \times Cp}$$

where,

á - Thermal diffusivity of the sample, m_2 s_{-1}

K_c - Thermal conductivity of the sample, W m_{-1}

K_{-1} Cp - Specific heat of the sample, KJ Kg_{-1} K_{-1}

ñb - Bulk density of the sample, Kgm_{-3}

Volumetric heat capacity

Volumetric heat capacity, also termed volume-specific heat capacity describes the ability of a given volume of a substance to store internal energy while undergoing a given temperature change, but without undergoing a phase change.

Knowing the thermal conductivity and thermal diffusivity of the sample, the volumetric heat capacity was calculated using the following the equation

(Abhayawick *et al*., 2002).

$$Cv = \frac{Kc}{\alpha}$$

where,

C_v - Volumetric heat capacity, J m^{-3} K^{-1}

K_c - Thermal conductivity, J s^{-1} m^{-1} K^{-1}

á - Thermal diffusivity of the sample, m_2 s_{-1}

Textural properties

The stable micro system - Texture Expert Exceed equipment along with 2.46 version software was used to find out the crushing load and penetration load or puncture load.

Puncture or penetration load

Puncture load is the force required for pushing a probe into a product to a depth that causes irreversible crushing. A head of a flat-end probe (4.0 mm diameter) was used to measure the puncture resistance of the onion bulbs using 50kg load cell. Force required to penetrate upto a depth of half of the diameter of the onion bulbs was obtained from the force – deformation plot using stable micro system – Texture Expert Exceed 2.46 version software.

Crushing load

Crushing implies the partial destruction of onion. Onion was set upon a Heavy duty platform with the P/75 -75 mm diameter aluminum platen probe was brought in contact with the onion. Compression force was applied by 50 kg load cell for partial destruction and then the force recorded under the prescribed conditions. It was indicated that the peak force before a sudden drop as traced on a force-deformation plot produced stable micro system – Texture Expert Exceed 2.46 version software.

Quality properties

Quality parameters or market value includes the moisture content, total soluble solids, colour and pyruvic acid content of the onion bulbs.

Moisture content

Fresh and three months stored onion bulbs were peeled manually by removing the skin and the first layer, and sliced. Slices were placed on perforated trays made of metal, and dried in a ventilated hot air oven at 55 °C till a constant weight was obtained.

(Abhayawick.*et al.,* 2002). The observations were recorded and weighed on an electronic balance to a precision of 0.01 g. The moisture content was calculated using the following equation (AOAC, 1990).

$$M_{wb} = \frac{W_1 - W_2}{W_1} \times 10$$

Where,

M_{wb} - Moisture content, per cent wet basis

W_1 - Initial weight of the sample, g

W_2 - Final weight of the sample, g

Total soluble solids

The total soluble solids are primarily sugars like sucrose, fructose and glucose. Tartaric acid and minerals in the juice also contribute to the soluble solids. The total soluble solids present in the onion bulbs were determined by using pocket refractor meter PAL-1 (ATAGO) which had a range of 0-53 %. Known quantity of onion bulbs were crushed by using pestle and mortar. The crushed juice was kept on the refractometer directly and the value obtained as per cent / degree Brix.

Colour

Colour flex meter (Hunter Associates Laboratory, Inc., model : 65/10°) was used for the measurement of colour of the onion. It provides a reading in terms of L, a, -a, b, - b and rE indicates the deviation in reflection *ie.* Change in total colour. 'a' value – measures redness when positive, grey when zero and greenness when negative. A transparent glass cup filled with sample was placed over the port and closed by using opaque cover (which provides a light trap to exclude the interference of external light). Positive 'a' value was noted for the fresh and three months stored onion bulbs.

Pyruvic acid content

Onion has the characteristic of being pungent only when its tissue is sliced. Pyruvic acid is among the onion constituents that influence pungency. The determination of pyruvic acid is a good estimate of fresh onion flavor and can be positively correlated with the sensory evaluation (Farag *et al.,* 1981). The pyruvate analysis was done according to Randle and Bussard (1993) method. Six gram of bulbs was taken and ground in pestle and mortar with 15 ml of phosphate buffer. The extract was centrifuged at 25,000 rpm for 15 minutes and the supernatant was used as a plant extract.

The standards were prepared by pipetting out 50, 75, 100,150 and 200 µl of pyruvate standard solution and 0.5, 1.0, 1.5, and 2.0 ml of sample extract into test tubes and then the volume was made up to 2.0 ml by adding phosphate buffer. A blank solution was also run. Then 0.5 ml of DNPH solution was added to all the test tubes and incubated at 37°C for 30 minutes. Then 5 ml of NaOH solution was added to all the test tubes mixed well and incubated for 10 minutes at room temperature. Absorbance of each sample was recorded at 610 nm. A standard graph was drawn, the amount of pyruvic acid present in the sample was calculated using the graph and the value expressed in $\mu molg^{-1}$.

Results and Discussions

All the properties were assessed at an average moisture content of 83.45±1.10 per cent (wb) for the fresh onion bulbs and 81.82 ±1.01 per cent (wb) for the three months stored onion CO 4 verities.

Thermal properties

Table. 1. shows the average values, SD and CV of the thermal properties such as specific heat, thermal conductivity and thermal diffusivity of fresh onion cultivar.

Specific heat

Specific heat of fresh and three months stored onion bulbs were 4.21 ± 0.01 and 3.27 ± 0.015 kJ/ kg °K with the CV values of 0.25 and 0.45 per cent. Abhayawick *et al.,* (2002) reported similar results for sweet vaidalia and Niz varieties of onion at the moisture content of 85.81 and 81.34 per cent (wb) respectively. This property varied linearly with moisture content.

Table 1. Thermal properties of the fresh and three months stored CO 4 cultivar

Particulars	Fresh onion			Stored onion		
	Mean	SD	CV (%)	Mean	SD	CV (%)
Thermal conductivity (W/m K)	0.55	0.09	17.04	0.47	0.06	12.14
Specific heat (kJ/kg K)	4.205	0.01	0.25	3.273	0.015	0.45
Thermal diffusivity (m^2/s)	2.43 x10^{-7}	3.69 x10^{-8}	15.18	3.50 x10^{-7}	3.75 x 10^{-8}	10.71
Volumetric heat capacity (J/m^3 K)	2.27 x10^6	7.28 x 10^4	0.032	1.34 x10^6	2.75 x 10^4	2.06

Thermal conductivity

Thermal conductivity of fresh and three months stored onion bulbs was 0.55 ± 0.09 and 0.47 ± 0.06 W/m K with the coefficient of variance of 17.04 and 12. 14 per cent respectively. Similar studies conducted on sweet vaidalia and Niz varieties of onion gave the thermal conductivity value of 0.55 and 0.47 W/m K at the moisture content of 85.81 and 81.34 per cent (wb) (Abhayawick *et al.,*2002). Thermal conductivity of onion increased with increase in moisture content.

Thermal diffusivity

The average thermal diffusivity values of fresh and three months stored onion bulbs were 2.43 x 10^{-7} ± 3.69 x 10^{-8} and 3.50 X 10^{-7} ± 3.75 x 10^{-8} m^2/s with the CV values of 15.18 and 10.71 per cent. Thermal diffusivity of onion was found to be increased after three months stored onion bulbs due to decreased moisture content thus increased the porosity and also reduced the size and shape. Similar trend was observed in the Arabica and robusta parchments of coffee varieties by Chandrasekar and Viswanathan (1999).

Volumetric heat capacity

The average value of volumetric heat capacity of fresh and three months stored onion bulbs were 2.27 x10^6 ± 7.28 x 10^4 and 1.34 x 10^6 ± 2.75 ÷ 10^4 J/ m^3 K with the coefficient of the variance 0.032 and 2.06 per cent respectively. Similar study was conducted by Jirickova *et al.,* (2006) for the granular agricultural products, namely of spring oat, wheat mixture Axis, barley mixture, corn mixture and soybean Evans.

Textural properties

Table.2 shows the average values, SD and CV of the penetration load and crushing load of fresh and three months stored onion.

Table 2. Textural properties of the fresh and three months stored CO 4 cultivar

Particulars	Fresh onion			Stored onion		
	Mean	SD	CV (%)	Mean	SD	CV (%)
Penetration load (N)	28.82	3.96	13.73	25.03	3.81	15.21
Crushing load (N)	146.97	24.76	16.85	70.46	15.33	21.76

Puncture strength or Penetration load

The mean values of penetration load of fresh and stored onion bulbs were 28.82±3.96 and 25.03 ±3.81 N with the coefficient of Variance from 13.73 to 15.21. This similar result of penetration load was observed for the Giza (20) onion around 27.60 ± 0.40 N and with the CV of 14.35 per cent. These values are in agreement with the results of Bahnasawy *et al*., (2004) with the mean penetration load of 27.60 ± 0.40 N and with a CV of 14.35 for the Giza (20) white onion cultivar (<4 cm-small) . The load required for penetrating or puncturing the fresh onion was more compared to the three month stored onion bulbs.

Crushing strength or crushing load

Crushing load of fresh and three months stored onion bulbs had mean values ranging from 146.97±24.76 to 70 ±15.33 N with the CV of 16.85 to 21.76 per cent respectively. The result showed that the force required for the crushing of fresh sample was two times more than the three months stored onion sample. The CV of the crushing load was high (21.76 %) for the three months stored onion and the lowest (16.85 %) for the fresh onion sample. The results indicated that the force required for crushing for the large size cloves was three times the value of the smaller size cloves. Similar result was observed by Bahnasawy (2007) for large size (>6cm) of garlic cloves which had a mean crushing load of 155±22.6 N.

Quality properties/parameters

Table 3 shows the average values, SD and CV of the quality properties *viz.,* moisture content, total soluble solids (TSS) and color of the fresh and three months stored onion cultivar.

Moisture content

An average moisture content of 83.45±1.10 per cent (wb) for the fresh onion bulbs and 81.82 ±1.01 per cent (wb) for the three months stored onion. In general it was observed that as storage days prolongs, the moisture content of the bulbs gets reduced. (Anbukkarasi, 2010).

Total soluble solids (TSS)

Total soluble solids (TSS) of fresh onion and three months stored onion bulb were 16.91±0.90 and 17.29±0.62 per cent respectively. These trends agree with the study conducted by Kukanoor (2005) for the initial and four months stored cv.53 onion bulbs whose total soluble solids (TSS) were 9.70 and 13.30 per cent respectively.

Table 3. Quality parameter of the fresh and three months stored CO 4 cultivar

Particulars	Fresh onion			Stored onion		
	Mean	SD	CV (%)	Mean	SD	CV (%)
Moisture content (wb %)	83.45	1.10	1.32	81.82	1.01	1.23
Colour (a*)	15.23	1.00	6.57	14.58	0.67	4.58
TSS (%)	16.91	0.90	5.31	17.29	0.62	3.56
Pyruvic acid (μmol/g)	4.58	0.41	12.45	4.25	0.39	15.14

Colour

'a*' values were 15.23±1.0 and 14.58 ±0.67 for the fresh onion bulb and three months stored onion bulbs with coefficient of variance of 6.57 and 4.58 per cent respectively. Results showed that the colour of the fresh onion bulb was purple red in colour which turned into the pale red colour after three months storage. Thus, there was a reduction of 4.27 per cent of red colour from the fresh to three months stored onion bulb.

Pyruvic acid

Pyruvic acid content of the fresh onion and three months stored onion bulbs was 4.58±0.41 and 4.25±0.39 μmol/g with the coefficient of variance of 12.45 and 15.14 per cent respectively. Similar trend was observed in the treated (Steeping - 2 min in top water-20°C) sliced Behairy onion with change in pyruvic acid content from 24.0 to 24.2 μmol/g during the three months of storage (Frang *et al.,* 1981). The minimum and maximum values of pyruvic acid content was noted from 2.29 to 2.48 μmol/g for the CO(On)-5 cultivar in the ventilation storage (Anbukkarasi, 2010).

Conclusion

The thermal, textural, and quality properties/ parameters of the fresh and three months stored CO 4 onion bulbs were assessed at an average moisture content of 83.45±1.1 per cent (wb) for the fresh onion bulbs and 81.82 ±1.01 per cent (wb) for the three months stored onion. Specific heat, thermal conductivity and volumetric heat capacity values decreased with increase in storage period and decrease in moisture content. Thermal diffusivity of the onion was found to be increased with the decrease in moisture content. Thus an increase in thermal diffusivity was observed in the three months stored sample as compared to fresh onions.

Penetration load required for penetrating or puncturing the fresh onion was high compared with the three months stored onion bulbs. For the crushing strength, force required for the crushing of fresh onions was two times more than the three months stored onion sample.

The moisture content of three months stored onion bulbs was lower compared with fresh sample. Total soluble solids content was high in three months stored onion as compared to fresh sample.

In fresh sample the colour value 'a' was high compared with the three months stored onion. The colour of the fresh onion bulb scales changes from purple red to pale red colour after three months storage. The pyruvic acid content of three months stored onion bulbs was low compared to the fresh sample.

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