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Designing and development of laboratory scale ohmic pasteurizer and its effect on ascorbic acid in Amla juice

Chinmay Joshi[1*], Iranna Udachan[2]
[1, 2] Food Technology Division, Department of Technology, Shivaji University, Kolhapur, Maharashtra, India

Abstract
Amla is one of the popular fruits which is rich in fiber, carbohydrate, iron and considered as the one of the richest source of ascorbic acid (vitamin C). Pasteurization is the conventional method given to fruit juices for preservation which has drawbacks such as degradation of the nutritional compounds, overheating, loss of nutrients and sensory changes. Vitamin C being heat sensitive reduces drastically during pasteurization. Therefore, use of alternate non-thermal technologies for preservation is needed. Ohmic heating is a non-thermal processing technology which includes passage of alternating electric current through foods where heat is internally generated due to electrical resistance. A laboratory scale ohmic heating equipment was manufactured. Amla juice was pasteurized by laboratory scale ohmic pasteurizer in batch-wise manner. The results were compared with the juice pasteurized by conventional method. It has been found that there was more retention of vitamin C in amla juice pasteurized by ohmic heating as compared to that of by conventional pasteurization. Juice processed by both methods was found to have similar sensory quality. Therefore, application of non-thermal treatments results in preservation of essential nutrients in food.

Keywords: non-thermal technologies, ohmic heating, pasteurization, preservation, vitamin C

1. Introduction
Fruits are a major source of dietary antioxidants that impart health benefits beyond nutrition. Fruits comprise vitamins, proteins, minerals and dietary fibres. Drinking fruit juices is highly favoured in many countries and also an efficient way to improve consumption of fruits. Citrus juices are considered to be the most popular beverages among all the fruit juices as citrus fruits are very famous for high content of vitamin C; which plays an important role in reducing the risk of many diseases originating from oxidative stress. Fruits are perishable in nature and thus, there is a need to process fruits in order to increase their storage or shelf life significantly.

Amla or aonla (*Emblica officinalis*), popularly known as Indian gooseberry is rich in fibre, carbohydrate, iron and is reported as the richest source of vitamin C [11]. Conventional heating methods like pasteurization influence the ascorbic acid content in amla juice. The juice suffers from loss of vitamin C and severe browning during storage particularly at higher temperature, which adversely affects the appearance, nutrition and overall acceptability of juice [3].

Ohmic heating is non-thermal technique which is defined as a process wherein electric current is passed through food materials where food is get heated as a result of internal heat generation due to resistance to current passage, resulting in rapid and uniform temperature increase within the food. Ohmic heating is less influenced by change of thermal properties of foodstuff compared to other heating methods. The efficiency of ohmic heating especially for fruit juices is generally high since the conversion ratio of the electrical energy to heat energy is very high.

2. Materials and Methods
2.1 Preparation of amla juice
Amla fruits were purchased from the local market of Kolhapur, Maharashtra, India and necessary pre-treatments such as washing, sorting, etc. were carried out. The fruits were further cut into pieces and seeds were removed. The amla pieces were ground with equal proportion of water and the juice was strained out [32].

2.2 Designing and development of ohmic heating equipment
A laboratory scale ohmic heating equipment was manufactured on the basis of available materials with their best compatibility and sources. There were two main parts of the set-up viz. heating chamber in which juice was kept for pasteurization and heating system which was mainly an electrical system. Heating chamber included a readymade cylindrical vessel (15cm in height and 12.5cm in diameter) with tight fitting lid made up of food grade stainless steel (SS 316). The capacity of vessel was 1500 ml. The detachable lid was used in order to protect the juice from direct sunlight as well as atmospheric oxygen during pasteurization. The lid of the vessel was pierced/drilled at 5 equidistant points. One of the piercing was done at the geometric centre from where the temperature of juice could be measured by inserting thermocouple. The rest four piercing were done at 2 cm and 4 cm away on the both sides of the central point for insertion of electrodes within the chamber. The chamber was finally fitted within a polystyrene box for insulation purpose.

For electrical system, the required electrical components AC voltmeter, fuse, connectors, push switch were procured from local market. The circuit was firstly designed and fitted in a wooden box for insulation, stability and safety purposes with provision of two connecting terminals. Two wires fitted with detachable connectors were connected to the circuit at the connecting terminals for the passage of current. The other ends of the wires were connected to the electrodes.

Power from general domestic electrical supply (230V, 50Hz) was used for experiment. Voltage variac (0-270V AC, 5A) was used to regulate voltage during experiment. The electrodes used were of food grade stainless steel (SS 304). The length of the electrodes was about 16 cm and diameter was 2 mm. The electrodes were inserted in heating chamber through the pierced points during experiment with insulating electrode fitters made up of Bakelite.

Fig 1: Heating chamber of laboratory scale ohmic heating equipment

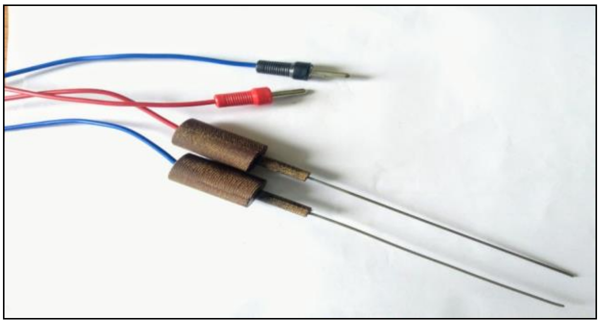

Fig 2: Electrodes from electrical system

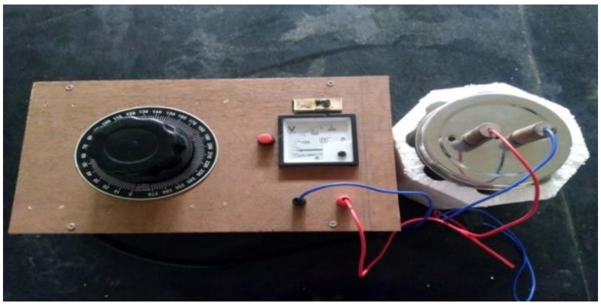

Fig 3: Experimental laboratory scale ohmic heating equipment

2.3 Pasteurization of amla juice by ohmic heating

Pasteurization of amla juice by ohmic heating was carried out with manufactured experimental ohmic heating equipment setup. The juice was kept in heating chamber and electrodes were dipped within. The electrodes were connected to the electrical heating system with the help of connectors and electric current was allowed to flow through the juice. The juice was heated to 80°C temperature. Holding time was kept 180 seconds for the batches. Once the temperature of the juice reached to 80°C, the equipment was switched off and, it was again switched on when the temperature of juice was 79.5°C or below. Heating time and holding time were recorded during the process. The batches were further compared with conventionally processed juice.

2.4 Optimization of process variables during pasteurization of Amla juice by ohmic heating

The process of pasteurization of amla juice by ohmic heating was carried out with varying process parameters. Voltage gradient and distance in between electrodes were the process variables used during the experiment.

2.5 Optimization of voltage gradient during pasteurization

Amla juice was pasteurized at different voltage gradients as 20, 30 and 40 V/cm. Six different batches of amla juice namely O_1, O_2, O_3, O_4, O_5 and O_6 were pasteurized using varying voltage gradients.

Table 1: Voltage gradients used for pasteurization of amla juice by ohmic heating

Sr. No.	Amla juice batch	Applied voltage gradient (V/cm)
1	O_1	20
2	O_4	
3	O_2	30
4	O_5	
5	O_3	40
6	O_6	

2.6 Optimization of electrodes distance during pasteurization

The distance between electrodes was varied during the experiment along with voltage gradients. Since, the piercing were done at 2 cm and 4 cm away on the both sides of the central point on the lid, the distance between the electrodes was maintained as 4 and 8 cm. All the six batches of amla juice (O_1, O_2, O_3, O_4, O_5 and O_6) were pasteurized with varying electrodes distance.

Table 2: Electrodes distance kept during pasteurization of amla juice by ohmic heating

Sr. No.	Batch	Distance between electrodes (cm)
1	O_1	
2	O_2	
3	O_3	4
4	O_4	
5	O_5	
6	O_6	8

2.7 Pasteurization of amla juice by conventional heating

The amla juice was pasteurized conventionally by ‘open pan’ method. The juice was heated in an open vessel to 80°C temperature. Four batches namely C_1, C_2, C_3 and C_4 were pasteurized by varying holding time as 300, 600, 900 and 1200 seconds. Once the temperature of the juice reached to 80°C, heating was stopped and, it was again started when the temperature of juice was 79.5°C or below. During pasteurization, the rise in temperature was measured at every 120 seconds time interval. Heating time and holding time were recorded during the process.

Table 3: Pasteurization of amla juice by conventional heating

Sr. No.	Batch	Holding time (seconds)
1	C_1	300
2	C_2	600
3	C_3	900
4	C_4	1200

2.8 Quality evaluation of amla juice
2.8.1 Analysis of ascorbic acid content
Ascorbic acid was estimated by 2, 6 - dichlorophenol-indophenol (DCPIP) visual titration method [26].

$$\text{Ascorbic acid (mg/100ml)} = \frac{\text{Titre x dye factor x volume made up x 100}}{\text{Aliquot of filtration x volume of sample}}$$

2.8.2 Sensory evaluation of amla juice
Sensory evaluation of the amla juice samples was carried out by a panel of ten judges for different sensory attributes such as colour, flavor, taste (astringency), consistency and overall acceptability using nine-point hedonic scales, where 9 = extremely like and 1 = extremely dislike [26].

2.9 Statistical analysis
Analysis of variance (ANOVA) was calculated by Turkey's method ($p<0.05$). Results from all the tests were obtained as means ± SD of triplicate experiments (n=3).

3. Results and Discussions
3.1 Effect of voltage gradient on processing time during pasteurization of amla juice by ohmic heating

Table 4: Effect of voltage gradient on processing time during pasteurization of amla juice

Sr. No.	Batch	Voltage gradient used (V/cm)	Process time (seconds)
1	O_1	20	1630±2.51
2	O_2	30	780±1.52
3	O_3	40	490±2.51
4	O_4	20	1560±1.52
5	O_5	30	865±1.15
6	O_6	40	550±3.05

From Table 4 it can be seen that, batches O_1 and O_4 required 1630 and 1560 seconds respectively for pasteurization when voltage gradient 20 V/cm was used while, the total process time was lowered up to 490 and 550 seconds for batches O_3 and O_6 respectively when voltage gradient 40 V/cm was used. These results revealed that, the total process time of the juice batches was reduced considerably during pasteurization when higher voltage gradients were used.
Voltage gradient is the prime aspect in ohmic heating process. It has noteworthy effect on processing time. Higher voltage gradients induced higher current to pass through the juice, which ultimately resulted in accelerated rate of electrical charge transfer within the circuit. Therefore, use of higher voltage gradients in pasteurization resulted in lowering the process times. The results obtained in present investigation shows resemblance with the results reported by other researchers [12, 13].

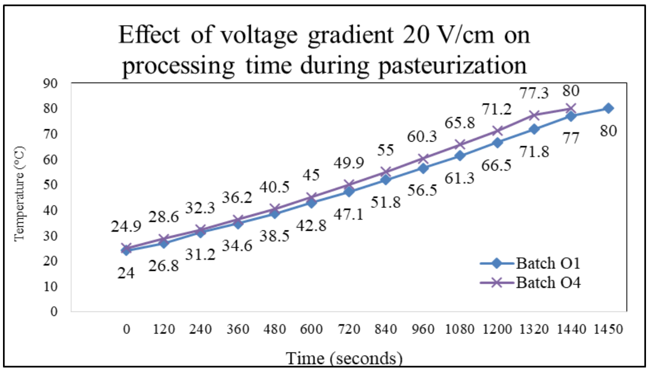

Fig 4: Effect of voltage gradient 20 V/cm on processing time during pasteurization of amla juice batches O1 and O4

From Figure 4, it was observed that there was progressive increase in temperature of the juice along with time during pasteurization process. Though there was variation in the distance between electrodes, temperature curves with respect to time of both the batches O_1 and O_4 were obtained similar in pattern. Process time taken by batch O_1 was lagged behind as that of O_4 by 70 seconds. Therefore it was concluded that, batch O_4 had lesser process time as compared with that of O_1 and hence, process time of 1560 seconds was found ideal for pasteurization of juice when voltage gradient 20 V/cm was used with electrodes distance was 8 cm.

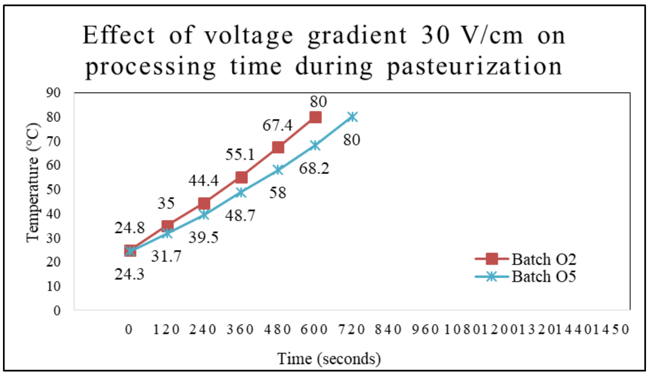

Fig 5: Effect of voltage gradient 30 V/cm on processing time during pasteurization of amla juice batches O2 and O5

From Figure 5, it was observed that there was uniform rise in temperature of the juice along with time. Though there was variation in the distance between electrodes, temperature curves with respect to time of both the batches O_2 and O_5 were obtained almost in similar pattern. Process time taken by batch O_2 was less than that of O_5 by 85 seconds. Therefore it was concluded that, batch O_2 had lesser process time as compared with that of O_5 and hence, process time of 780 seconds was found ideal for pasteurization of juice when voltage gradient 30 V/cm was used with electrodes distance was 4 cm.

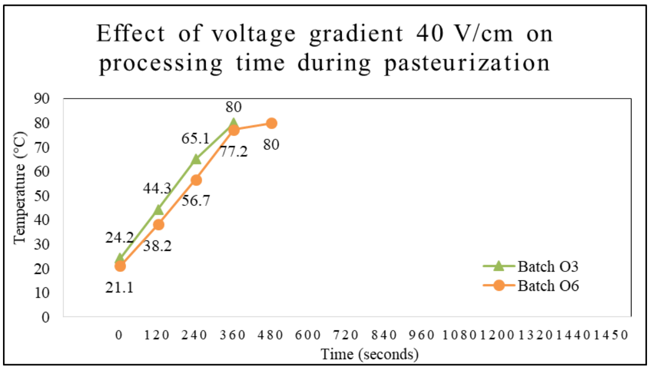

Fig 6: Effect of voltage gradient 40 V/cm on processing time during pasteurization of amla juice batches O3 and O6

From Figure 6, it was observed that there was rapid increase in temperature of the juice along with time. Though there was variation in the distance between electrodes, temperature curves with respect to time of both the batches O_3 and O_6 were obtained of identical pattern. Process time taken by batch O_3 was less than that of O_6 by 60 seconds. Therefore it was concluded that, batch O_3 had lesser process time as compared with that of O_6 and hence, process time of 490 seconds was found ideal for pasteurization of juice when voltage gradient 30 V/cm was used with electrodes distance was 4 cm.

3.2 Effect of voltage gradient on temperature during pasteurization of amla juice by ohmic heating

The effect of voltage gradient on temperature during pasteurization was studied with respect to time. It is obvious that there was rise in temperature of the juice during pasteurization. The increase in temperature with respect to time is the rate of temperature rise. The temperature of amla juice was measured at every 120 seconds during the process and the rate of temperature rise was calculated from the data obtained. It was reported as °C/sec. and °C/min. In case of pasteurization by ohmic heating, the rate of temperature rise was dependent mainly on initial juice temperature and voltage gradient applied.

Table 5: Effect of voltage gradient on rate of temperature rise during pasteurization

Sr. No.	Amla juice batch	Rate of temperature rise during pasteurization, °C/sec. (°C/min.)
1	O_1	0.0366±0.00 (2.2±0.00)
2	O_2	0.092±0.04 (5.52±0.04)
3	O_3	0.1703±0.00 (10.22±0.00)
4	O_4	0.0396±0.00 (2.38±0.00)
5	O_5	0.0723±0.05 (4.34±0.05)
6	O_6	0.1558±0.00 (9.35±0.00)

From Table 5, the results showed that the rates of temperature rise were ranged in between 0.0366 to 0.1703°C/sec. (i.e. 2.2 to 10.22°C/min.). There was remarkable variation in rates of temperature rise. The highest rate of temperature rise was found to be 0.1703°C/sec. (i.e. 10.22°C/min.) which was of batch O_3; pasteurized using voltage gradient 40 V/cm. Whereas, the lowest rate of temperature rise was found to be 0.0366°C/sec. (i.e. 2.2°C/min.) which was of batch O_1; pasteurized using voltage gradient 20 V/cm. Therefore it was found that, the rate of temperature rise was higher when higher voltage gradient was used.

Voltage gradient has remarkable effect on process time as well as on temperature. Use of higher voltage gradients caused lowering of process time as a result of increased rate of temperature rise. Thus, voltage gradient is directly proportional to the rate of temperature rise whereas, it is inversely proportional to the process time. Therefore, as the voltage gradient (V) increased, temperature (T) increased and process time (t) decreased.

$$V \propto T \propto \frac{1}{t}$$

3.3 Effect of electrodes distance on processing time during pasteurization of amla juice by ohmic heating

The effect of electrodes distance on process time during overall process is summarized in Table 6 and 7.

Table 6: Effect of electrodes distance on processing time during pasteurization at 4 cm

Sr. No.	Batch	Process time (seconds)
1	O_1	1630±2.51
2	O_2	780±1.52
3	O_3	490±2.51

From Table 6, it was observed that the values of process times of the batches were varied considerably. There was remarkable reduction in total process time found at voltage gradients of higher value. Batches O_2 and O_3 were found to have lower process times as compared with that of batch O_1.

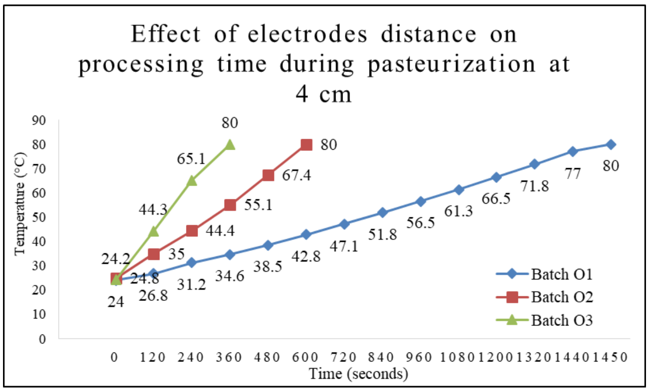

Fig 7: Effect of electrodes distance at 4 cm on processing time during pasteurization of amla juice batches O1, O2 and O3

From Figure 7 it was observed that, though the distance between electrodes was same for the batches during pasteurization, the temperature curves with respect to time of the juice batches were different along with time. Process times taken by the batches O_1, O_2 and O_3 were 1630, 780 and 490 seconds respectively. Thus, the results revealed that the process time taken by batch O_1 was lagged behind as that of O_2 by 850 seconds and of O_3 by 1140 seconds.

The temperature curves of the batches O_2 and O_3 were found almost similar. However, process time taken by batch O_2 was lagged behind as that of O_3 by 290 seconds. It was observed that, voltage gradient had more influence on the temperature curves than the electrodes distance throughout the process.

Table 7: Effect of electrodes distance on processing time during pasteurization at 8 cm

Sr. No.	Batch	Process time (seconds)
1	O_4	1560±1.52
2	O_5	865±1.15
3	O_6	550±3.05

From Table 7, it was observed that the process times were varied considerably as like of previous case. There was remarkable reduction in total process time at higher voltage gradients. Batches O_5 and O_6 were found to have lower process times than that of batch O_4.

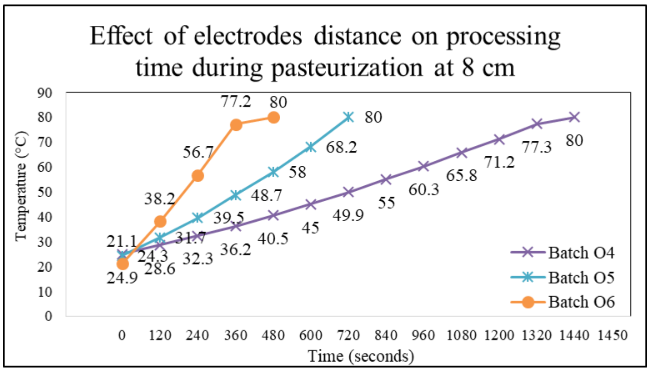

Fig 8: Effect of electrodes distance at 8 cm on processing time during pasteurization of amla juice batches O4, O5 and O6

From Figure 8 it was observed that, though the distance between electrodes was same for the batches during pasteurization, the temperature curves of the juice batches were different along with time. Process times taken by the batches O_4, O_5 and O_6 were 1560, 865 and 550 seconds respectively. Thus, the results revealed that the process time taken by batch O_1 was lagged behind as that of O_2 by 695 seconds and of O_3 by 1010 seconds.

Batches O_5 and O_6 were found to have quite lesser process times. However, process time taken by batch O_5 was lagged behind as that of O_6 by 315 seconds. Thus, similar results were observed in case of electrodes distance 4 and 8 cm. Voltage gradient had more influence on the temperature curves than the electrodes distance.

From Table 6 and 7, it was observed that the values of process times of the batches were varied to a wide range. Though there was difference in between electrodes distance, process time for the batches O_1 and O_4 was found nearer to each other. Similar pattern was observed for batches O_2 and O_5 and O_3 and O_6 also. The process time for batch O_1 was obtained as 1630 seconds when the distance between electrodes was 4 cm, which was quite higher than that of for batch O_4 when the distance between electrodes was 8 cm (1560 seconds). On the other hand, the process times for batches O_2 and O_3 were obtained as 780 and 490 seconds respectively which were quite lesser than that of for batches O_5 (865 seconds) and O_6 (550 seconds) respectively. Thus, process time was found to get reduced during pasteurization when the distance between electrodes was 4 cm as compared to that of 8 cm at voltage gradients 30 and 40 V/cm.

As the distance between electrodes increased, the area of the electric field of the complete circuit increased and hence, the time required to charge transfer from one point to other point had increased. Therefore the results revealed that, the distance between electrodes had significant effect on heating time at higher voltage gradients (30 and 40 V/cm).

3.4 Process time taken for pasteurization of amla juice by conventional heating

From Table 8, it can be seen that the batches C_1, C_2, C_3 and C_4 took 380, 390, 427 and 400 seconds for reaching the pasteurization temperature respectively. Although the method of heating was same, time taken by the batches to reach the pasteurization temperature were varied to some extent. The difference in between heating times was because of initial juice temperature.

Table 8: Process time taken for pasteurization of amla juice by conventional heating

Sr. No.	Batch	Heating time (A) (seconds)	Holding time (B) (seconds)	Total process time (A+B) (seconds)
1	C_1	380±1.52	300	680±1.52
2	C_2	390±2.51	600	990±2.51
3	C_3	427±3.21	900	1327±3.21
4	C_4	400±4.04	1200	1600±4.04

3.5 Retention of Vitamin C in amla juice during storage

The retention of vitamin C in amla juice during 45 days of storage was studied. From Table 9, it was found that there was gradual degradation in vitamin C. The degradation showed the heat sensitivity of vitamin C. Activity of enzyme polyphenol oxidase (PPO) was mainly responsible for the degradation of vitamin C during storage period. The highest retention of vitamin C was found in batches O_1 and O_4 (27.30 mg/100ml and 26.57 mg/100ml respectively) which were pasteurized by ohmic heating while, the highest degradation of vitamin C was found in batch C_4 (8.36 mg/100ml) which was pasteurized by conventional method. Thus, the results revealed that there was significant retention of vitamin C in juice batches pasteurized by ohmic heating as compared with that of by conventional heating.

Table 9: Retention of vitamin C in pasteurized amla juice batches during storage

Sr. No.	Batch	Vitamin C (mg/100ml) No. of days 0	15	30	45
1	O_1	91.07±0.71	73.14±0.80	59.01±0.69	27.30±0.80
2	O_2	84.10±0.70	67.58±0.40	57.86±0.40	23.14±0.59
3	O_3	79.54±0.75	63.97±0.73	53.64±0.73	19.26±0.13
4	O_4	88.86±0.75	71.28±0.73	58.23±2.15	26.57±0.17
5	O_5	80.72±0.27	64.21±0.84	53.23±1.32	22.63±0.78
6	O_6	76.62±0.83	63.93±0.72	52.85±0.30	18.74±0.12
7	C_1	88.28±0.71	75.92±0.42	49.25±0.70	16.60±0.10
8	C_2	78.52±0.70	64.12±0.41	47.10±0.71	12.03±0.81
9	C_3	70.16±0.69	59.25±0.40	46.75±0.80	10.60±0.76
10	C_4	69.18±0.43	57.61±0.69	45.19±0.70	8.36±0.05

3.6 Sensory evaluation of amla juice

Amla juice pasteurized by ohmic heating and conventional heating was subjected to sensory evaluation. The observations of judges were recorded based on a 9 point hedonic scale (9 and 1 points shows like extremely and dislike extremely). The results with respect to sensory evaluation of pasteurized amla juice are presented as follows.

Table 10: Results of sensory evaluation of pasteurized amla juice

Sample/Parameter	Colour	Flavour	Taste (Astringency)	Consistency	Overall acceptability
Control	5	4	3	7	5
O_1	8	7	7	8	7
O_2	8	7	7	8	7
O_3	7	7	6	7	6
O_4	7	7	7	8	7
O_5	7	7	7	7	7
O_6	7	6	6	8	6
C_1	7	6	7	7	7
C_2	7	6	6	7	7
C_3	6	7	7	8	7
C_4	6	6	6	8	6

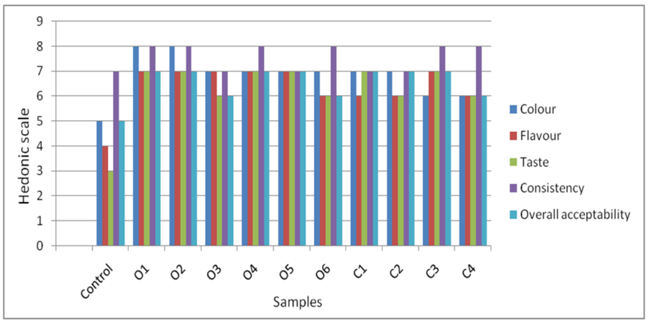

Fig 9: Results of sensory evaluation of pasteurized amla juice

From the Table 10, it can be seen that all the juice samples acquired scores for sensory attributes in similar pattern. Although all the batches were varied in processing methodology and process variables, no any remarkable difference was found in any of sample by the judges during sensory evaluation. Thus, juice samples processed by both methods were found to have similar sensory quality. Ohmic heating was found to have no any detrimental effect on the sensory quality of juice.

4. Conclusion

Citrus fruits are very famous due to its high content of vitamin C, which plays an important role in prevention of several diseases. Amla juice was pasteurized by ohmic heating and conventional heating method. The objective of the study was reduction in the process time of pasteurization with maximum possible retention of vitamin C in the juice. It has been found that, voltage gradient is the most important process parameter that defines overall process profile. It is directly proportional to temperature and hence, the process time was reduced to almost more than half at higher values of it. There were remarkable significant changes in juice pasteurized by ohmic heating than conventional one. Reduction in total process time and higher retention in vitamin C content was found in juice pasteurization by ohmic heating.

Storage study of 45 days revealed that there was degradation in vitamin C irrespective of method of pasteurization. However, the rate of degradation of vitamin C was found to be lesser in case of juice pasteurized by ohmic heating as compared with the juice pasteurized by conventional method. Thus, reduction in total process time and higher retention in vitamin C content was found in juice pasteurized by ohmic heating. Results of sensory evaluation showed that ohmic heating had no any remarkable or objectionable effect on the sensory quality of juice. Therefore, it can be concluded that use of non-thermal techniques like ohmic heating should be applied instead of conventional methods for processing of food products.

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