Performance Evaluation of an Automatic Tomato Paste-Making Machine

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ORIGINAL RESEARCH

Abstract- Tomato is a highly perishable fruits that deteriorates faster, hence, the need for immediate processing. Tomato paste is a common processed products mostly done manually that involves drudgery. To reduce drudgery and realize a quality tomato paste, an automatic tomato paste-making machine was developed and evaluated for its performance. The major performance evaluated was the sensory evaluation of the processed tomato paste. The machine was developed from stainless steels and PVC pipes that are non-contaminating local materials. The automatic electronic components were developed by soldering of Integrated Circuits, timers, relays, diodes, thermostats, blenders, heaters and plug in conformity with the designed circuit diagram. The machine was evaluated by running it with no load and when fed with 3 kg tomato fruits at varying steaming and blending times of 3, 4, 6 and 4, 6 and 10 minutes respectively. The sensory evaluation was then conducted through subjective evaluation of a 5-man taste panel employed to evaluate 45 samples of tomato pastes based on their homogeneity and smoothness/coarseness. Results revealed that the automatic components of the machine work satisfactorily to its design purpose. The best tomato pastes certified as extremely good by the panelists were produced at higher steaming time of 6 minutes and blending time of 4, 6 and 10 minutes. It was established that there was correlation of taste quality of tomato with steaming time and as well entwine with the blending time. As the steam time increases, blending becomes easier and quality of paste was also observed to improve.

Keywords- Automatic, Electronic, Tomato paste, Sensory evaluation.

1 Introduction

Tomato (*Lycopersicon esculentum* Mill.) is categorized under fruits and vegetables, but specifically fruits. It is one of the most popular fruits worldwide (SaeedAwan *et al*., 2012) as it constitutes daily meal of every household. Tomato fruits contain about 96% moisture and other liquid-soluble materials, making it a tender and compression-sensitive fruits (Olanrewaju *et al*., 2021 and Babarinsa and Ige, 2014). It is a highly perishable crop that deteriorates soon after harvest, hence, calls for processing. Tomato fruits can be processed into several products that are food based and industrial raw materials. Common among the domestic by-products tomato fruits are juice, paste, powder, and industrial by-products are syrup, vitamin C, and puree. Tomato paste has been identified to be a popular product processed from tomato fruits. To affirm this statement, Nigeria has been reported to be among the largest importer of tomato paste in the world (Ugonna *et al*., 2015), leading to several local industries like Gino, Dangote, Tomato Jos, to indulge in tomato paste processing. Individual interactions and personal surveys also revealed that some farmers have started processing their tomato fruits into paste at domestic levels, rather than allow them to be wasted. However, processing at domestic level is done manually and laborious. Domestic tomato paste production among farmers can be improved through the development, promotion and adoption of a labour-saving machine, expected to increase agricultural productivity, encourage tomato farmers, and enhance domestic growth.

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To mechanize tomato production at domestic level, an automated tomato paste-making machine can be a game changer among tomato fruits stakeholders.

Agricultural productivity, quality and economic growth of a country can be increased through automation and smart agriculture. Studies has revealed that agricultural practices as practiced in the mid-1990s has experienced some major changes, especially in areas like domestication of crops and animals, weed control techniques, water management, fertilizer/pesticides application, genetic engineering and mechanization through long term and low-tech alternatives in agricultural mechanization and automation. The speed of information processing of data collected in fields can assist to rapidly grow the agriculture sector using precision technologies discovered by innovations that result in various revolutions worldwide (Koprda and Magdin, 2015; Bachche, 2015; Seema, *et al*., 2015). Numerous researches have been conducted on automation in agriculture, few among them are the study of Nouri-Ahmadabadi et al. (2017) that developed an intelligent system that works with Machine Vision (MV) and Support Vector Machine (SVM) that sorts peeled pistachio kernels and shells. Images were taken and digitized using a colour CCD and capture card before they are transferred to a computer for further analysis. The SVM achieved the best accuracy at 99.17%, overall sorter accuracy of 94.33% and capacity of 22.74 kg/h. Momin *et al.* (2017) developed an image acquisition and processing system to automate the grading of mangoes considering projected area, perimeter, and roundness. Images were acquired with a high-resolution camera, processed with algorithm capable of colour binarization that classified mangoes into large, medium and small. It has an accuracy of 97% for the projected area, 79% for perimeter and 36% for roundness. It was recommended that two different grading features be used in sequence to achieve finer grading. Moreover, a digital technology (automation) was used to simplify and reduce manpower in agricultural sector. A sensor that detects humidity, temperature, fertilizers and pesticides was designed to work in wired and wireless environment. The sensor was designed to convert mechanical (natural environment) into digital environment. Simulation was done using *intellisuite* software with finite element method at various levels of observations on the sensor. The designed sensor was reported to achieve its function (Kalaiyazhagan *et al.*, 2018). An algorithm for fruit sorting using computer vision was also developed by Seema *et al.* (2015). Image processing in agriculture was reviewed to provide an insight into the use of vision-based systems highlighting their advantages and disadvantages. Bachche (2015) conducted a study by collating 30 years information on various design strategies in recognition and picking systems in fruits harvesting robots. The high-tech, precise and qualitative large-scale modern agriculture industry of today is a result of evolutions in time and different inventions in agriculture. The present era of modern high-tech and precision agriculture is producing quality produce.

Olanrewaju *et al.* (2022) developed an automatic tomato paste-making production machine that operates using Arduino principle. The machine operates on the automatic principle of powering on and off the heater that steam the tomato fruits and the blender that milled them. A time for carrying out these operations are preset and the machines operates at this time and stops as set. This machine was reported to perform its basic designed function. The objective of this research was to evaluate the performance of the earlier machine with main focus on the sensory evaluation of the paste processed from the automatic tomato paste-making machine.

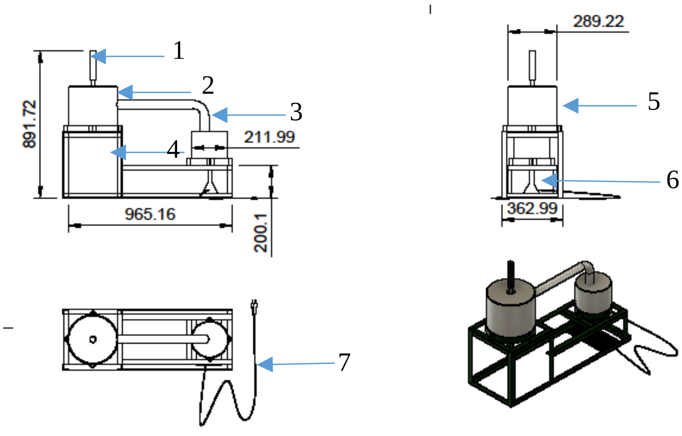

Fig. 1: Orthographic and Isometric views of the automatic tomato paste production machine.

1– Handle, 2– Steaming pot, 3– Connecting pipe, 4– Frame, 5– Blending pot, 6– Blender, 7– Electric cable.

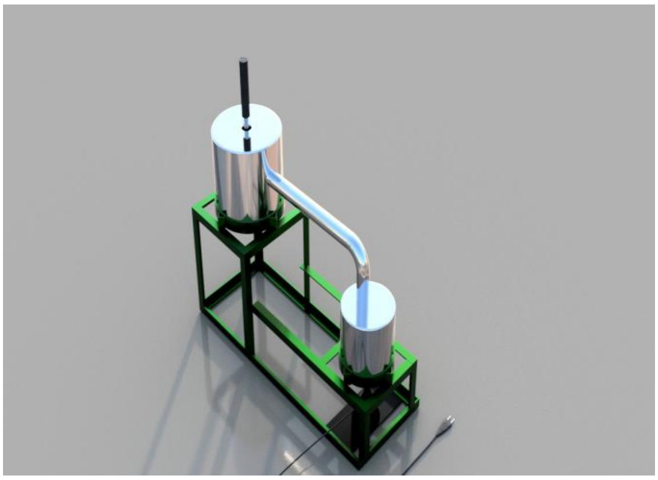

Fig. 2: Pictorial view of the tomato paste machine

2 Materials and Methods

The tomato paste-making machine was developed. Its components include frame, steaming and blending pots, connecting pipe, and the automatic circuits which were welded, bolted, screwed and wired. The frame was made from mild steel angle iron. The steaming unit was made from a stainless-steel pot with perforated base positioned above a water bath and a heater. Blending unit was also fabricated from stainless steel material. A bought-out blender and the steamer were connected by a 3 mm PVC pipe. The machine views are presented in figures 1 and 2 (Olanrewaju et al., 2022).

2.1 Operating Procedure

Water is poured and heated to boiling point below the steamer. The steam from the boiled water rises by convection to the tomato fruits to soften it in readiness for blending. A stirrer positioned at the middle of the steamer is rotated intermittently to ensure uniform reception of steam by the tomato fruits. After a preset time, the heater trips off and the blender start up automatically. The steamed tomato moves through the PVC pipes into the blending unit. The inner component of the blending unit has a conically wrapped stainless steel that ensures propulsion during blending to achieve uniform blending of the tomato fruits into a homogenous paste.

2.2 The Automatic Electronic Unit

The automatic electronic unit was designed and fabricated from series of Integrated Circuits (IC), timers, relays, diodes, thermostats, blenders, heaters and plug. These materials were soldiered to a board according to the design of the circuit diagram presented in Figure 3. The outlook of the automation unit after arranging, soldering, and coupling is shown in Figure 4. The plug is connected to a socket. V_1 represent an alternating voltage source of 220V. This voltage is used two ways in the entire circuit. Components including the Blender B_1, Heater H_1 and Contact Relays RL_1 and RL_2 uses the entire 220V alternating voltage from V_1 while other electronic components use a 12V direct current (DC) derived from V_1 via Voltage Step-down, rectification and filtration processes. TX_1 is transformer unit used for stepping down the voltage from 220V (AC) to 12V (DC). The 12V output is fed into two Rectifier Diodes D_1 and D_2 to rectify to 12V (DC). Capacitor C_1 is used to remove AC ripples (filtering) from the rectifier diodes' output. The output of C_1 is fed into Zener diode (7812). The 7812 diode is used to ensure that a constant DC voltage of 12V is frequently supplied to the electronic components even if the values of V_1 fluctuate. The 12V DC voltage is supplied to the remaining electronic components in the circuit.

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Integrated Circuits IC_1 and IC_2 are 555 timers. They are used to time Blender B_1 and Heater H_1. R_1, C_2 and R_2, C_3 are used to control the timing of IC_1 and IC_2 respectively. This timing (t) is related to an associated resistor R and Capacitor C of a 555 timer by equation 1.

$$R = \frac{t}{1.1C} \tag{1}$$

R_1 and R_3 are variable resistors which can be tuned to control the timing of Blender B_1 and Heater H_1. D_4 and D_5 are Light Emitting Diodes (LED) used as indicators for the operation of Heater H_1 and Blender B_1. Q_1 and Q_2 and other associated components (resistors and capacitors) performs the task of switching the Contact Relays RL_1 and RL_2 respectively. These Contact Relays RL_1 and RL_2 respectively switch ON/OFF of Blender B_1 and Heater H_1 based on the timing of IC_1 and IC_2 (Olanrewaju *et al.*, 2022).

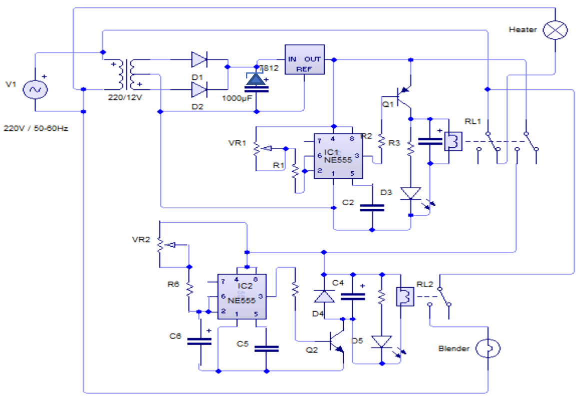

Fig. 3: Circuit diagram of the automation unit

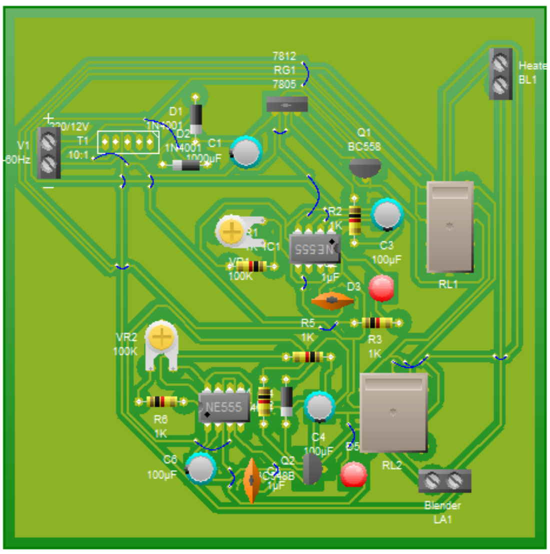

Fig. 4: Pictorial view of the automation board

2.3 Methods Of Evaluation

The developed tomato paste machine was evaluated for its performance in three (3) stages. The first stage was to test the mechanical and automation component if they performed the functions they were designed. The second stage was to test the factorial combination of the pretreatments to ensure that the timers for steaming and blending worked effectively and efficiently. The third and final stage is the evaluation of the product (tomato paste) collected at different steaming and blending time.

2.3.1 Mechanical/Automation Evaluation

Mechanical evaluation was done to ensure that the frame, connecting PVC pipe, bolts and nuts and other joints were tested for vibration and lose parts. The automation evaluation was done on the major components of the automatic units, which are the steamer and blender; hence, time was preset for the steamer and blender. Literatures consulted indicated that average steaming time for tomato fruits are usually between 5 - 10 minutes while blending time mostly takes between 7 and 15 minutes which are variety dependent (Olanrewaju, 2012). To ensure that the timers for both the steamer and blender perform optimally, preset time of 3, 4 and 6 minutes for steaming while 4, 6 and 10 minutes for blending were considered. Combination of steaming and blending time (treatments) gave 9 runs for the tests conducted as presented in Figure 5

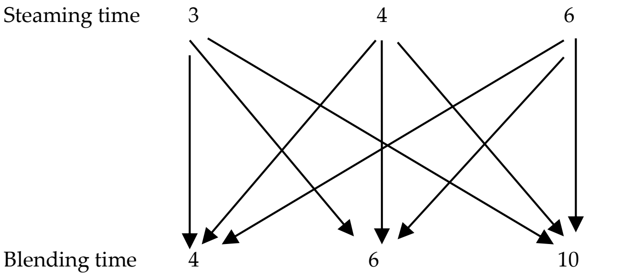

Fig. 5: Factorial Design of the Machine Testing

2.3.2Product Evaluation

After certifying that both the mechanical and automatic part of the machine are working, another set of tests were run on the output of the machine, that is, the tomato pastes produced by this machine at the stated treatments planned in Figure 5 above. Fresh Roma Vf tomato fruits variety at grape vine maturity were purchased from Ipata market in Ilorin, Kwara State. They were washed and sorted to remove foreign materials, and spoilt ones that could contaminate the paste. The fruits were weighed to avoid choking the steaming and blending chambers and also to ensure uniform reception of steam. Clean tomato fruits of 3 kg were fed into the machine. The steaming and blending time were preset using the factorial design in figure 5. The paste produced from each preset steaming and blending time were then subjected to a sensory evaluation by some trained human tasters. It is recommended that footnotes be avoided; instead, try to integrate the footnote information into the text.

2.3.3 Sensory Evaluation

The sensory evaluation is the test the tomato pastes produced by the machine was subjected to, in order to determine the palatability and acceptability of the paste. A subjective sensory evaluation was conducted on the tomato pastes. This was done by engaging human testers who are termed professional panellists. They were recruited through referrals from Food Technology and

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Home Economics Departments and also from popular food vendors around town, aged between 20 – 35 years. A 5-man panellist was engaged and blind folded to taste 9 samples of 3 replicates of tomato pastes produced, totalling 45 samples were tasted for 9 days. The choice of 9 days was to allow the individual taste samples to fade off their taste buds and disallow for mix up of any sort. The sensory characteristics commonly evaluated are colour, taste, flavour and texture, however, colour and flavour were assumed to be uniform in this study as they were produced from the same variety and no additives was added. Therefore, tastes and texture (homogeneity and roughness/coarseness of the pastes) were the key characteristics that was evaluated and these was graded into 3-scale which are extremely good, moderate and dislike. Responses of each taster were collated and tabulated in Table 1. The average tastes and cumulative taste outputs are presented in Table 2 and Figure 6.

4 Results and Discussion

Results of the evaluations conducted on the machine and its product is presented in Table 1 and Figure 5 below. The codes A1, A2, A3, B1, B2, B3, C1, C2, and C3 represent the combination of steaming and blending time which are 3,4; 3,6; 3;10: 4,4; 4,6; 4,10: 6,4; 6,6; 6,10 respectively.

Table 1. Average results of the taste panels

Steaming/ Blending time combination	Taste Panel 1	Taste Panel 2	Taste Panel 3	Taste Panel 4	Taste Panel 5
A1	Z	Z	Z	Z	Z
A2	Z	Z	Z	Z	Z
A3	Z	Y	Z	Y	Z
B1	Y	Y	Y	Z	Y
B2	Y	Y	-	Z	Y
B3	Y	-	Y	Y	-
C1	X	Y	X	Y	X
C2	X	Y	Y	X	X
C3	X	X	Y	X	X

X – Extremely Good; Y – Satisfactory; Z – Dislike

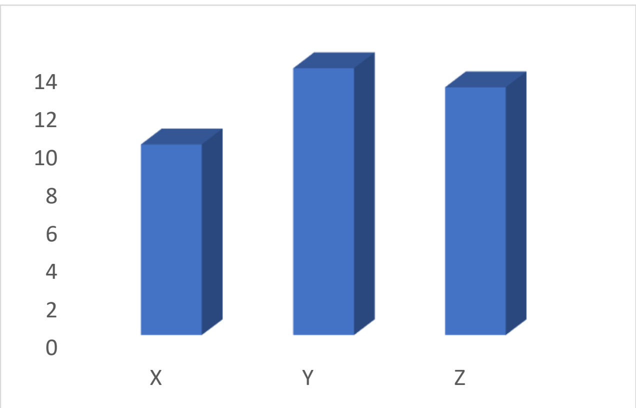

Fig. 6: Overall evaluation of the Tomato Paste

4.1 Discussion

Results of physical observations during the mechanical/automatic evaluation revealed that all welding joints, bolts and nuts were properly fixed and intact during the machine operation. The preset timing sensors on the machines were also found to be operational as designed (Olanrewaju *et al.*, 2020).

Furthermore, the 3 kg tomato fruits fed into the machine to evaluate the products were blended at all the varying preset time. No choking or clogging was observed during this operation, especially during the discharge from the steaming pot through the PVC pipe into the blender. More so, the steaming and blending time performed optimally as preset. Though, varying paste homogeneity was observed for the different samples of steaming and blending time.

Finally, during the sensory evaluation, most of the blended tomato paste from the machine were reported to be satisfactory. The batches that were reported to be disliked by the taste panels were those with lesser steaming time, that is 3 minutes. The paste output from this combination were reported to be coarse and not homogenous, hence, making them generally unacceptable for consumption. Conversely, the best of the pastes was reported to be at higher steaming time of 6 minutes. Pastes at this steaming time were reported to be homogenous and smooth to taste, hence, extremely good and largely acceptable to prepare any kind of delicacies. However, batches that fell in the satisfactory category were those with steaming time of 4 minutes. Pastes at this steaming time were reported to be satisfactory and generally applicable for many delicacies, even those with health challenges.

The general outlook of the collective results of the taste panels is presented in Figure 6. It is obvious in that Figure that14 out of the valid 42 tests were satisfactory, 10 were extremely good and 12 were reported to be disliked and 3 samples were undecided. It could be deduced from this result that taste quality of tomato paste is greatly correlated with the steaming time which is as well entwine with the blending time. As the steam time increases, blending becomes easier and quality of paste was also observed to improve. This is confirmed by the studies of Dogan et al. (2003), Zhang et al. (2014), Sheta et al. (2017), Olanrewaju et al. (2022), Rodriguez et al. (2001) Muhammad et al., (2010) and Nkhata and Ayua (2018).

5 Conclusion

The automatic tomato paste machine produced was novel among local technology and its performance were observed to be satisfactory. The mechanical/automatic and product evaluation of the machine when evaluated met up with its design purpose. The performance of the machine can actualize possibilities of automation in food processing industries, especially at small and medium scale levels in Nigeria. Quality tomato paste that is acceptable for general use was produced at steaming time of 6 minutes and blending time of 4, 6 and 10 minutes. The machine is easy to operate, maintain and as the name implies; automatic – no supervision required during operation.

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