Pak. J. Agri. Sci., Vol. 47(4), 383-387; 2010
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
http://www.pakjas.com.pk

DEVELOPMENT OF A MACHINE FOR COLD PULPING OF TOMATO

Khawaja Altaf Husain, Muhammad Shafi Sabir and Muhammad Iqbal

Department of Farm Machinery & Power, University of Agriculture Faisalabad, Pakistan
Corresponding author's e-mail: fmpkah@gmail.com

The study was taken up to investigate the existing methods of tomato processing for pulp and fabricate an indigenous machine which may operate under room temperatures to isolate pulp, seed and peel from fresh tomato without heating activity. Machine parameters, such as the roller surface (flat & serrated), variation in roller clearance and rotational speed were employed for experimentation of cold pulping of tomato. All of these factors were employed in CRD statistical design with three replicates each. The analysis of variance was carried out using PROC GLM (general linear model) SAS-2009. The quality and recovery of pulp and seed were tested to establish the performance of the machine for cold pulping. Greater pulp rate (483.71 g/min; 90 % pulp approx.), 8 % seed and 2 % peel were obtained in case of red ripe tomatoes because of their lower rupture strength than the ripe one's. Greater rotational speed and larger diameter of rollers resulted in more pulp recovery while roller clearance played an inverse role, yielding less pulp recovery in case of larger clearance. Higher pulp production was achieved by serrated rollers rather than that with flat or plain rollers.
Keywords: Tomato pulp, roller, diameter, clearance, strength

INTRODUCTION

Tomato is one of the significant fruit/vegetable crop popularly being consumed in all over the world. Tomatoes are consumed either as fresh fruit/vegetable or as processed products (Gray and Tchamitchian, 2001). In the near future, every hectare of available land will be required to attain at least 200% cropping intensity with selective crop farming and high yielding traits. This crop has the potential to produce 26.840 tones/ ha (77.67 max. no. of bolls per plant), where as present average yield in Pakistan is 10.6 tones/ ha (Anonymous, 2007). Mechanized vegetable farms are rarely functional in Pakistan agriculture. A significant feature of this vegetable is its consistent consumption world wide, used in many forms, from fresh to processed types.

There are many methods of tomato processing involving engineering and technological means (Dall'argine and Ghiretti, 1976; Dall'argine and Ghiretti, 1975, Savi, 1984). The large and small industrial units are engaged in processing of tomato in various forms by using a temperature gradient of 70°C to isolate peel and seed from pulp, destroying seed altogether and thus sacrificing pulp quality. Tomato peel is removed by a process of suction creating vacuum under temperature control which results in destroying seed viability (Battistini, 1986; Levati, 1977). This study was also carried out to remove skin of the tomato by heating and engaging peeling mechanism, whereas lycopene and seed were not recovered with mechanical processes conducted by Silvestrini (1985) and Silvestrini (1982).

Tomato seed is not successfully produced in Pakistan and need is there to improve conditions in producing local seed for expanding production area as well as improving the pulp quality for better utility in different forms. There is an ample scope of exploring the ways to utilize a machine to achieve cold pulping of tomato under normal temperature condition. Accordingly the farming community and manufacturers are to be provided a technically sound, economically feasible and widely acceptable solution of value addition at the farm gate which may avert the low income generating system into high profit receiving mechanism and change the fate of poor stake holders at large.

Thus the objectives of conducting this study were to develop and fabricate a tomato pulp extraction machine, to establish the machine parameters for cold pulping of tomato and to assess the effect of different machine parameters on quality and tomato pulp recovery rate.

MATERIALS AND METHODS

This study was carried out with an aim to develop and test an appropriate pulp extraction machine for cold pulping of tomato (under normal temperature condition). Entirely locally available material was used for the development and fabrication of different components of the machine. A 0.746 kW (900 rpm) variable speed gear electric motor was used to operate the pulping unit. Two stainless steel serrated rollers (26 cm diameter, 30 cm length) were used to compress and squeeze out the pulp and seed from the peel of tomato. A stainless steel sieve (40 No.) was procured, fabricated and installed in a centrifuge (2250 rpm motor) of 30 cm diameter and 20 cm height to separate pulp from seed and peel. The schematic diagram of newly developed and fabricated machine is shown in Fig.1.

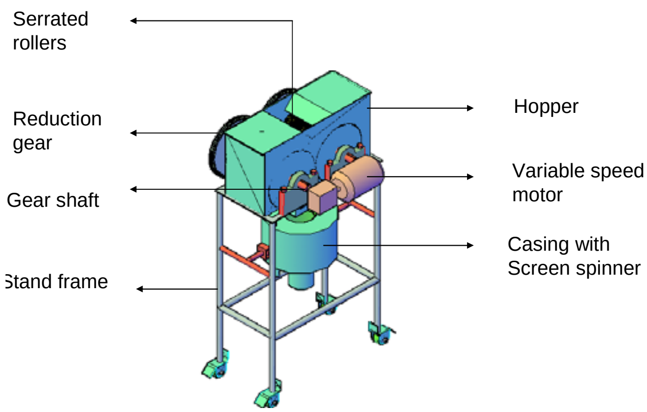

Figure 1. Schematic view of tomato cold pulping machine

A 0.746 kW (2250 rpm) electric motor was used for the centrifugal unit of machine, and power requirement analysis was done using tomato size, roller diameter and roller rpm as variables, relationship between the three parameters was developed with the help of graph for serrated rollers in Fig. 2 and 3.

The machine consisted of a hopper, rollers and gears shaft, journal bearings and gears centrifugal spinner with strainer, rollers and gears, centrifugal spinner main frame three phase electric motor and gear with panel board

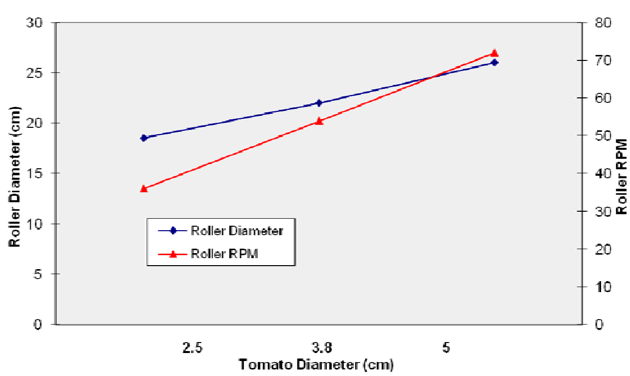

Figure 2. Relationship between tomato size, roller diameter and roller rpm with serrated rollers at 1 mm clearance.

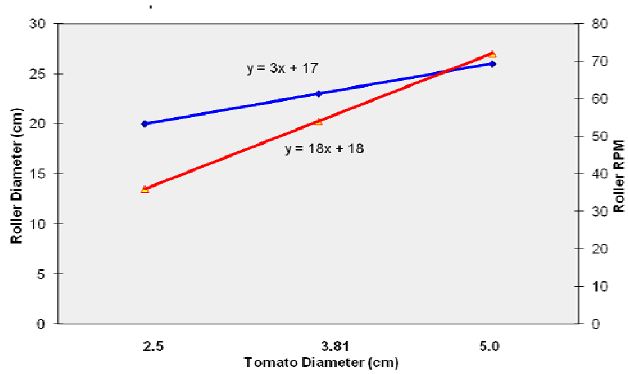

Figure 3. Relationship between tomato size, roller diameter and roller rpm with serrated rollers at 2 mm clearance.

A 14 gauge M.S sheet (Mild steel) was used to fabricate a hopper of suitable size (60 cm x 40 cm x 20 cm) with 30^{o} side inclination in order to accommodate a batch of 5-kg tomatoes. The gauge size was selected keeping into consideration, the durability and optimal weight and price and of the unit. Moreover, a non corrosive material was coated onto the hopper unit.

Rollers (Fig. 4) are the pivotal elements which are used to compress and squeeze out the pulp and seed from the peel of tomato. Non-corrosive material was employed in order to maintain the quality standards of the pulp and seed extracts.

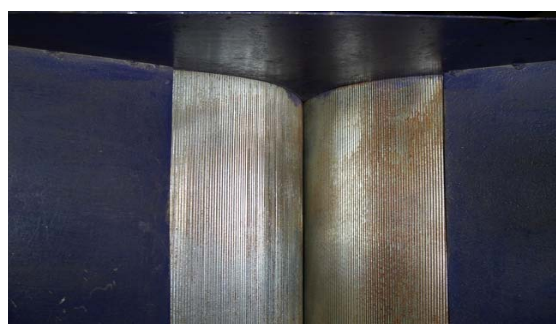

Figure 4.

The 10-gauge galvanized steel sheet material was procured to fabricate sets of rollers of the required sizes.

Two sets of rollers were serrated and the other two roller sets were kept plain (18.5 cm and 26 cm diameters respectively) for test purposes. Specifications of rollers are given in Table 1.

A 30 mm diameter solid shaft {8620-HRC (58-60)} of 50 cm length was used for each roller individually. The shaft ends of both the rollers were supported on either end on the journal bearings. On one end of the shaft, provision for the installation of variable speed motor was made. The other end of the shaft was keyed to the reducing gear unit. The entire mechanism of rotating shaft was mounted on journal bearings bolted to the main frame (Fig. 5).

Table 1. Specification of rollers

Roller type	Diameter (cm)	Length (cm)	Numbers
Serrated	18.5 26.0	30 30	2 2
Plain	18.5 26.0	30 30	2 2

Figure 5. Pictorial view of variable

In order to transmit power from variable speed motor, to reducing gears (Fig. 6), spur gears having 88 teeth, were used to get the required speed and the desired direction (Fig. 7). The selection of gears was made according to the procedures described by Khurmi and Gupta (2001). The designed tangential tooth load was obtained from the power transmission and pitch line velocity by using the relationship suggested by Khurmi.and Gupta (2001).

$$W_t = \frac{P * 4500 * C_s}{V}$$

Where, W_t= permissible tangential tooth load, P is the power required in kW , V is the pitch line velocity in m min^{-1}, C_s is the service factor constant and V is given by the following relation

$$V = \frac{\pi DN}{100} = \frac{\pi mTN}{100}, \text{ m min}^{-1}$$

where, m = module in cm, T is the number of teeth, D is the pith circle diameter in cm, N is the speed in rpm

A perforated stainless sheet of 40 No. mesh size was procured for fabrication of a sieve and installed in a centrifuge of 30 cm diameter and 20 cm height. The upper side of the bowl shaped centrifuge had an opening of 15-cm diameter to receive the extracted material from the roller casing funnel. The lower side of centrifuge sieve, bolted onto a one centimeter thick, 30-cm diameter plate, coupled to a 2-cm shaft of 0.746 kW of 2250 rpm motor (Fig. 8).

Figure 6. Pictorial view of journal bearing

Figure 7. Picturorial view of spur gears

Figure 8. Pictorial view of centrifugal casing with strainer spinner

In order to accommodate the centrifuge strainer to gauge spinner, a round hollow casing of 40 cm diameter and 30 cm height was fabricated from a galvanized steel sheet of 10 gauge thickness size. The unit was hooked on two sides of the frame in order to tilt over and clean out the seed and peel from the sidewalls of centrifuge screen embodied in the casing. The upper end of the casing had a detachable cover with a 15-cm opening in the center to accommodate the exit end of funnel of roller casing from above. The lower end of the casing received the pulp screened out from the centrifugal strainer and simultaneously

discharged through a three centimeter diameter hole into a five liter container below.
A 5 x 0.3 cm angle iron frame of mild steel was used to fabricate main frame dimensioning 60 cm long, 40 cm wide and a height of 90 cm. The dimensions of the angle iron and that of frame had been selected taking into account the static and dynamic load of machine components and durability of pulping machine. Four wheels were fixed on the frame for easy and prompt maneuverability of machine.
On the tomato pulp machine, a three phase electric panel board was installed with two circuit-breakers one for 2250 rpm of 0.746 kW motor and the other for a 900 rpm of 0.746kW variable speed motor as shown in Figure 9. A timer had also been installed to maintain simultaneous clockwise and anticlockwise spin each for 30-seconds of the centrifugal strainer spinner.

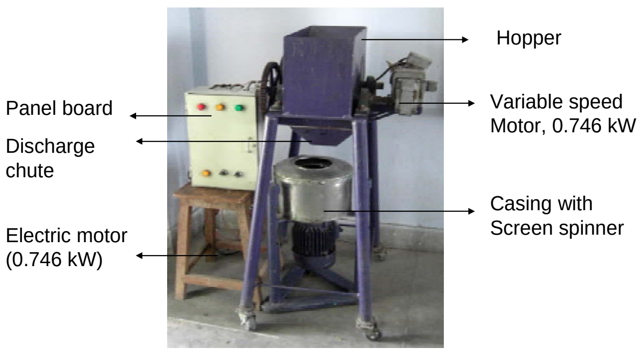

Figure 9. Pictorial view of newly developed machine with stand and electric panel board

RESULTS AND DISCUSSION

Efforts were made to segregate pulp of tomato from its seeds and peel under normal conditions without using any extra heat energy. The effect of different machine parameters like roller type (T), roller diameter (D), roller clearance (C), and roller speed (N) were thoroughly investigated. The ANOVA tables were developed using PROC GLM (General Linear Model) procedures of the SAS Institute (2009). Covariates analysis was performed and regression models were developed to estimate the contribution of each machine parameter considered/studied towards pulp characteristics. The statistically analyzed results are discussed as follows.

Effect of roller diameter on pulp extraction rate and pulp percentage: The effects of two levels of roller diameters on pulp extraction rate (PR) and pulp percentage (PP) were statistically analyzed and it was observed that the greater diameter of roller significantly produced more (PR) and (PP) in all the varieties of tomatoes both in serrated and plain rollers. The greater PR and PP with larger diameter rollers than those with smaller diameter rollers could be due to the reason that there was more surface area of rollers in contact with tomato surface which might had increased adhesion force between tomato and rollers resulting in more grip of rollers and hence more extraction of pulp from tomato.

Effect of roller type on pulp extraction rate and pulp percentage
Serrated rollers produced significantly greater pulp rate (1.026 times greater) and pulp percentage (1.006 times greater) than those with plain rollers (Table 2). This may be attributed to the fact that the serrations on the cylinder surface could have penetrated into the tomato surface during pulping which would have increased grip on the tomato and broken the soft tissues of tomato, hence resulted in more PR and PP.

Table 2. Effects of roller type (pooled effect)

Roller type	**Pulp rate** (g/min)	**Pulp percentage**
Serrated (Group 1)	487.09 a	88.70 a
Plain (Group 2)	474.46 b	88.11 b
Mean	480.77	88.41
LSD (0.05)	1.076	0.0721

Means followed by the same letters in each column are not significantly different at 5% level of probability.

Effect of roller clearance on pulp extraction rate and pulp percentage: To assess the pulp recovery, two roller clearance levels (1mm and 2mm) were selected. The statistically analyzed data regarding PR and PP have been presented in Table 3. The results show that lesser roller clearance produced significantly greater pulp rate than that produced at greater roller clearance. It is also clear that the reduction in roller clearance from 2 to 1 mm increased PR on an average of 2 %. This could be due to the fact that smaller the roller clearance, greater would be compaction/extrusion of tomato tissues, resulting in greater amount of pulp recovery.

Table 3. Pooled effect of roller clearance over other machine and crop parameters

Roller clearance (mm)	**Pooled Pulp rate** (g/min)
1	486.38 a
2	475.17 b
Mean	480.77
LSD (0.05)	1.049

Means followed by the same letters in each column are not significantly different at 5% level of probability

Effect of roller speed (RPM) on pulp extraction rate and pulp percentage: The pooled effect of roller speed on other machine and crop parameters for pulp recovery were statistically analyzed and presented in Table 4. Higher roller speed (72 rpm) produced significantly greater value of PR and PP for all the three tomato varieties (Nagina, Roma and Moneymaker) and both sizes of rollers than those produced by lower roller speed (36 rpm). The pooled effect of roller speed over all the other parameters indicated that the higher roller speed produced 483.71 g/min of PR as compared with lower speed that produced 477.84 g/min. A general conclusion can be drawn that for serrated and plain rollers, larger the roller speed, more the roller momentum and aggressive pulp extraction at higher speed than that at lower speed which definitely helped in fast and easy pulp recovery from soft tissue.

It was found that the serrated roller at a speed of 72 rpm with 1 mm clearance having 26 mm diameter produced higher quantity and rate of tomato pulp. The developed tomato cold pulping machine was successfully assessed on red ripe and ripe tomatoes under normal temperature conditions giving maximum output of healthy seed along with maximum pulp extraction.

Table 4. Pooled effect of roller speed over other machine and crop parameters

Roller speed (rpm)	**Pooled Pulp rate** (g/min)
36	477.84 a
72	483.71 b
Mean	480.77
LSD (0.05)	1.0490

Means followed by the same letters in each column are not significantly different at 5% level of probability

CONCLUSIONS

From above discussions, following reasons can be advanced for the greatest and the lowest production of PR and PP:

1. The tissues of red ripe tomato might have less rupture strength than those for ripe tomato which had helped the machine to squeeze out more pulp rate and pulp percentage from red ripe tomato than the ripe ones.
2. The greater speed of rollers (72 RPM) had increased more momentum and inertial forces than that by the lower speed of rollers (36 RPM), hence resulting in more positive griping of tomato and more impact action for squeezing out increased PR and PP.
3. The roller clearance is inversely proportional to PR and PP production. At smaller clearance (C=1 mm), greater pulp recovery was achieved than that at larger clearance (C2=2 mm). This is due to the fact that at smaller clearance, all the tissues of tomato have been crushed till the complete extraction of tomato pulp.
4. Greater diameter of roller (26 cm) increased the contact area of rollers and tomato surface, which thus increased tomato grip during pulping, resulting in more pulp recovery than that with the smaller diameter roller (18.5cm).
5. Serrated rollers helped in increasing the grip over tomato surface that reduced slippage of tomato during pulping operations as compared with the plain rollers without serrations and hence resulted in more pulp rate and pulp percentage production.

REFERENCES

Anonymous. 2007. Tomato paste plant (3-5 tons/hr processing facility) at Killa Saifullah, Balochistan. Pakistan Horticulture Development and Export Board (PHDEB).

Battistini, I.N. 1986. Tomato peeling device operating through vacuum and temperature. United States Patent 4562772. Publication date 7 Jan. 1986.

Dall'argine, G. and E. Ghiretti. 1975. Shredding machine for tomato pulp intended for canning in the raw state. United States Patent 3878996. Publication date 22 April 1975.

Dall'argine, G. and E. Ghiretti. 1976. Squeezing-shredding machine for tomato pulp suitable for canning in the raw state. United States Patent 3933084. Publication date 20 Jan. 1976.

Gray, C. and M. Tchamitchian. 2001. Modeling and management of fruit production: the case of tomatoes. In L. M. N. Tijskens, M. L. A. T. M. Hertog and B. M. Nicolai (eds.), Food process modeling. CRC Press, Boca Raton, pp. 201-229.

Khurmi, R.S. and J. K. Gupta. 2001. *A Textbook of Machine Design*. Ram Nagar, New Dehli, India.

Levati, R. 1977. Machine for peeling tomatoes under vacuum. United States Patent 4026203. Publication date 31 May 1977.

Savi, A. 1984. Rotating-drum machine for peeling tomatoes. United States Patent 4437398.

Silvestrini, J.A. 1982. Apparatus for separating the pulp from the skin of fruit such as tomatoes. United States Patent 4355572.

Silvestrini, J.A. 1985. Method for separating the pulp from the skin of tomatoes. United States Patent 4493851.