Process protocol for mechanical separation of fruit core and seeds from apple fruits

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ABSTRACT

Apple seeds separated from apple pomace are utilized for raising apple nurseries by orchardists. Owing to crushing of seeds during juice extraction the germination capacity is very low with poor seed vigour. An attempt was made to develop a hand tool for separation of core from the fruit for its use in separation of seeds. Seeds were evaluated for their germination capacity for use in raising apple nurseries. On the basis of fruit and core dimensions mechanical corer consisting of coring tube internal diameter 22.1 mm, fruit holding cup and plunger device for moving the coring tube was developed. The coring efficiency of the mechanical apple corer (73.4 kg/h) was found about 5.12 times higher as compared to manual coring method (14.3 kg/h). Pre-treatment of fruit core by using pectinase (1%) enzyme for 24 hours was optimized for softening of the fruit core prior to seed separation. The softened fruit core was found suitable for passing through the mechanical seed separator for separation of seeds. The average seed extraction rate in mechanical seed separator (311.53 g/h) was found 18 times higher as compared to manual seed separation method (17.28 g/h) with negligible seed damage. The germination potential of the seeds separated through mechanical seed separator was found to be 89.9 per cent as compared to only 65.3 per cent germination recorded in seeds separated from apple pomace left after juice extraction. Thus method of mechanical separation of apple seeds can be adopted by the orchardists as well as fruit processing units to serve the apple industry for raising rootstocks.

Keywords: Apple; fruit and core dimensions; manual seed separation; mechanical apple corer

INTRODUCTION

Apple (*Malus domestica* Borkh) is an important fruit crop of northwestern Himalayan region of India. The maximum area and production of apple is in state of Jammu and Kashmir followed by Himachal Pradesh. Though the India's share in total world apple production is only 2 per cent (Anon 2009) yet it is a major horticultural produce and is the backbone of the rural economy of apple producing states. Total area under apple cultivation in India is 0.313 Mha with an annual production of 2.49 MT (http://nhb.gov.in/model-project-reports/Horticulture%20Crops/apple/apple1.htm). Central government through its agencies like National Horticulture Board (Government of India) and programmes like Mission for Integrated Development of Horticulture and National Horticulture Mission along with respective state governments aims to further increase total area and production under apple in the country. For this there is a huge demand of apple seed for raising fruit nursery. In Himachal hpmc (Horticultural Produce Marketing and Processing Corporation) is the major supplier of the seeds separated from the pomace but these seeds have poor germination and their genetic purity is unknown. On an average 10 quintals of the pomace yields about 1 kg of the seed from which about 10000 seedlings are produced. Thus the annual demand for apple seeds in Himachal Pradesh alone comes out to be about 400 kg seed per annum with at least 50 per cent seed viability (unpublished data). Himachal Pradesh alone reports a demand of 20 lakh plants annually and hpmc in the state is the major supplier of the seed extracted from the pomace. During apple processing any conventional process utilizes about 75 per cent of fresh weight of fruit while 25 per cent is left as waste including the valuable seed (Wang and Thomas 1989, Kaushal et al 2002). Recently pittoo grade and wild apple fruits (crab apple) have been used for vermin-composting in Himachal Pradesh though these fruits could have been used for separation of seed prior to its use in vermin-composting after separation of seed core; the fruits can still be used for processing purposes. However due to non-availability of the required tool and method the practice could not be put into use. Preliminary observations indicate that the manual separation of the seeds from the fruits is highly uneconomical as it is highly laborious and time consuming practice. This study was therefore proposed to fabricate a fruit corer suitable for removal of the seed core from various fruit grades of apple, to design suitable machinery for seed separation from the fruit core and to evaluate the germination potential of the separated seeds.

MATERIAL and METHODS

Fresh and uniformly mature apple fruits of seven different apple cultivars were procured from three major apple growing areas of Himachal Pradesh (Shimla, Kinnaur and Kullu) and brought immediately to the fruit processing unit of the department for experimentation. Fruit firmness, TSS, specific gravity and moisture content were analysed to ensure that the fruits were cored and the seeds separated at optimum maturity. Size parameters comprising vertical and horizontal diameter of fresh apple fruits were recorded with the help of vernier calipers.

Separation of fruit core

The fruits were cored manually as well as with mechanical apple core remover. In manual coring the fruits were hand-held and pressed against the cork borer (stainless steel) and the core so removed was collected separately. The coring efficiency was recorded as the weight as well as number of fruits cored per hour. The fruit core was used for separation of seeds while the fruits were utilized in preparation of various products.

Mechanical apple fruit corer

The mechanical apple corer as developed in collaboration with AICRP on FIM at PAU, Ludhiana, Punjab was evaluated for removal of cores from the fruits and the results were compared with manual coring. The mechanical corer consisted of a fruit holding cup measuring 80 mm in diameter where the fruits were placed in a vertical position facing a movable coring tube (22.1 mm diameter) made up of GI (galvanized iron) sheet of about 14 cm in length. The distance between the coring tube and the fruit holding cup was adjusted to 12.5 cm to enable placement of the fruit before coring. The coring tube was connected to a vertically moving handle which facilitated the movement of the coring tube into the fruit. The movable fruit coring tube was positioned inside a stable core collecting tube having a diameter and length of 24 mm and 18.5 cm respectively. The whole assembly was positioned on a wooden bench top. During operation of the fruit coring machine individual fruit was placed on the fruit holding cup in vertical orientation in a proper position. The coring tube was moved down and up with the help of a handle provided with spring and during this process the coring tube removed the core of the fruit which was collected in the core collection tray.

Seed separation from fruit core

After coring the fruits the method for separation of the seeds from the fruit core was optimized. Manual seed separation was carried out with the help of cutting knives. The core was cut into halves and the seeds were separated from the embryo cavity of the fruit manually. For mechanical separation of seeds fruit core (1 kg) was fed into the mechanical tomato seed separator. The core was first introduced into core crushing assembly of the machine where the blades cut the core into smaller pieces to loosen the embryo containing the seeds. The core then enters the seed separation chamber where the rotatory blades and paddles facilitate the seeds to pass through the sieve and are collected in the seed collection chamber located at the bottom of the machine and the larger pulp pieces pass the sieve off and come out through the outlet. The addition of water further facilitates the crushing process and seed separation process. The core so obtained was however very hard and the seed separation from such hard mass was difficult. Besides crushing of very hard core for longer duration resulted in damage to the seeds and accumulation of large amount of fine pulp in the seed collection pan. To overcome this problem efficiency of two enzymes viz pectinase and amylase to soften the fruit core prior to seed separation was evaluated. Fruit core was immersed in different concentrations viz 0.1, 0.25, 0.50 and 1 per cent of pectinase and amylase enzymes and kept for various intervals at 48°C for softening. Accordingly the macerating effect of both the enzymes was recorded as reduction in core diameter after 24, 48 and 72 hours of immersion. The enzyme, its concentration and time interval of the treatment exhibiting maximum softening of the fruit core were optimized for maceration of apple fruit core. The softened fruit core was then fed into mechanical tomato seed separator and results were compared with manual seed separation.

Seed stratification

After separation of seeds by both manual and mechanical methods the seeds were air-dried and subjected to cold stratification by placing them in polyethylene bags containing sand saturated with water. Small pinholes were made at the bottom of each bag to drain off excess of water from sand. The bags were placed in the refrigerator at 2 ± 1ºC temperature and 95 ± 2 per cent RH for a period of 2 months for stratification. After 60 days of cold stratification the seed coat started bursting indicating the completion of stratification period and beginning of seed germination.

Seed germination

The stratified seeds were collected and subjected to germination immediately after separation from sand to avoid desiccation. Seed germination of each cultivar was tested as per ISTA method (Anon 1985) in laboratory conditions using blotting paper method (Figs 1 and 2). Germination percentage of seeds separated manually as well as mechanically was worked out and compared with the seeds separated from apple pomace collected from commercial apple processing unit by using following formula:

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds placed for germination}} \times 100$$

Seedling length and dry weight

Ten healthy and robust seedlings were selected and their length was measured with the help of a digital vernier calipers. The selected seedlings were then air-dried in an oven for 24 hours at 100°C and seedling weight was calculated in mg.

Germination index

The germination index (GI) which is the parameter used to define the rate/speed of germination was computed using following expression:

$$GI = \frac{n}{d}$$

where n= Number of seedlings emerging on a particular day (d)

d= Days after planting

Seed vigour index

Seed vigour index-I (SVI-I) and seed vigour index-II (SVI-II) were calculated as per the formula given by Abdul-Baki and Anderson (1973). Seed lots which produced the taller seedlings were considered more vigorous as compared to the seed lots producing smaller seedlings.

Seed vigor index-I= Seed germination percentage × seedling length (cm)

Seed vigor index- II= Seed germination percentage × seedling dry weight (mg)

RESULTS and DISCUSSION

Size parameters of fruit

Size parameters of whole apple fruit viz average horizontal and vertical fruit diameter and fruit core viz core length and diameter are important for developing suitable machine for removal of apple core from whole fruit. Data in Table 1 show that the fruits utilized in the study were of four commercial grades viz pittoo (55 ± 2.5 mm), extra small (60 ± 2.5 mm), small (65 ± 2.5 mm) and medium (70 ± 2.5 mm) (Anon 1992). The horizontal fruit diameter of different cultivars ranged between 58.0-72.1 mm with maximum horizontal fruit diameter in Granny Smith (72.1 mm) and minimum (62 mm) in cultivar Spartan while culled apple fruits mainly used for processing were much smaller in horizontal diameter (58 mm). The horizontal fruit diameter is an important parameter which can be used to define the dimensions of the fruit holding cup and the diameter of the coring tube as the lager fruits exhibit larger core diameter. The vertical fruit diameter ranged between 52.9-68.9 mm. Similar to horizontal fruit diameter Granny Smith fruits exhibited highest vertical fruit diameter (68.9 mm) following Royal Delicious (60.4 mm), Gold Spur (60.3 mm) and Golden Delicious (57.0 mm) which were at par in vertical diameter while fruits of Spartan, Red Gold and culled

Table 1. Size parameters of whole apple fruit, fruit core and seed of different cultivars of apple

Apple cultivar	Parameter (mm)						
	Horizontal fruit diameter	Vertical fruit diameter	Core length	Core diameter	Seed length	Seed breadth	Seed thickness
Golden Delicious	62.1	57.0	53.4	17.9	7.91	4.02	2.13
Granny Smith	72.1	68.9	67.5	21.9	7.86	4.18	2.57
Gold Spur	62.3	60.3	58.5	17.9	8.53	4.50	2.37
Spartan	62.0	56.0	52.3	17.8	8.06	3.87	2.23
Red Gold	63.1	55.2	52.0	17.7	7.65	4.18	2.28
Royal Delicious	67.6	60.4	57.3	21.0	7.11	4.07	2.09
Culled Apple	58.0	52.9	49.9	15.9	7.82	4.18	2.17
$CD_{0.05}$	2.37	3.49	2.89	0.41	0.50	NS	NS

apples exhibited the smallest vertical diameter (52.9-56.0 mm).

Core dimensions viz core length and diameter of the core separated from different cultivars ranged between 49.9-67.5 and 15.9-21.9 mm respectively (Table 1). As expected medium grade fruits of Granny Smith cultivar exhibited maximum core length (67.5 mm) while pittoo grade fruits (culled apple) had lowest core length (49.9 mm) which was closely followed by Red Gold (52.0 mm) and Spartan fruits (52.3 mm). Further core diameter in different fruits ranged between 15.9-21.9 mm. On the basis of different grades of the fruits medium and small grade fruits exhibited a core diameter up to 22 mm with extra small grade 17.9 mm and pittoo grade fruits 15.9 mm. These observations signify a positive correlation between the horizontal fruit diameter and the core diameter. These parameters provide important information which can further be interpreted for fabrication of apple corer for different fruit grades with minimised loss of pulp during fruit coring.

Fruit coring

The coring efficiency of the coring device fabricated on the basis of the size parameters of the whole apple fruit and the fruit core was evaluated and compared with manual coring (Table 2). It is evident that the mechanical coring device was most effective as the coring efficiency was found to be 73.4 kg fruits/h (771.9 number of fruits/h) as against manual coring of only 14.3 kg fruits/h (154.8 number of fruits/h) in a unit time interval. Manual coring was 4-5 times less efficient compared to mechanical coring. The mechanical corer with coring efficiency of 764 apples/h was also found superior to the earlier mechanical device having coring efficiency of 250 apple fruits per hour (http://www.allindianpatents.com/patents/243803-pusa-fruit-coring-device-hand-operated). This higher efficiency of the mechanical corer may be attributed to the ease of handling the fruits and the indirect pressure applied through the handle of corer instead of the direct insertion of the corer into the fruit by applying pressure on the corer held against the fruit with the hand.

The fruit damage during coring either by manual or mechanical coring device was also evaluated. In comparison to mechanical coring the fruit damage was more under manual coring of the fruits. In manual coring 10.7 fruits were damaged per unit time during coring against 5.3 fruits damaged during mechanical coring (Table 2). Fruit damage is an important aspect as the fruits are utilized for further processing for making apple chips and rings where the damaged fruits can affect the product shape and its quality as well.

Seed separation

Seeds were separated from the fruit core by both the manual as well as mechanical methods. Total time taken for manual seed separation as well as the quantityof seed separated from fruit core was recorded and was compared with mechanical seed separation. However to soften the fruit core for easy core crushing and seed separation in mechanical seed separator the efficacy of enzymatic pre-treatments (pectinase and amylase) of fruit core was evaluated and standardized. Out of two enzymes applied within the concentration range of 0.1-1.0 per cent the use of pectinase (1%) was found most appropriate as it softened and reduced the core diameter from 21.1 to 8.5 mm within 24 hours of the treatment (Fig 1). On an average pectinase (1%) caused 61.5 per cent core softening. This reduction in core diameter may be attributed to the degradation of

Table 2. Effect of manual and mechanical methods of fruit coring on the efficiency of removal of fruit core and fruit damage in different cultivars of apple

Cultivar	Quantity of fruits cored/h				Number of fruits damaged/h		Mean (cultivar)		Mean (cultivar) fruits damaged/h
	C_1		C_2		C_1	C_2	Quantity (Kg/h)	Number of fruits/h	
	Quantity (kg)	Number	Quantity (kg)	Number					
Golden Delicious	15.0	152	75.3	756	11.0	4.0	45.2	454	7.5
Granny Smith	19.0	133	110.0	770	13.0	7.0	64.5	451	10.0
Gold Spur	13.0	160	65.3	782	10.7	4.7	39.2	471	7.7
Spartan	12.7	162	64.7	773	8.3	5.0	38.7	467	6.7
Red Gold	12.0	154	65.0	780	7.0	2.7	38.5	467	4.8
Royal Delicious	15.3	140	78.0	750	12.0	7.0	46.7	445	9.5
Culled Apple	13.3	182	55.3	792	12.3	6.7	34.33	487	9.5
Mean (method)	14.3	154.8	73.4	771.9	10.7	5.3			

C_1= Manual coring, C_2= Mechanical coring

$CD_{0.05}$

	Quantity of fruits cored	Number of fruits cored	Number of fruits damaged
Cultivar (C)	2.47	7.30	2.42
Method (M)	1.32	3.90	1.29
(C x M)	3.49	10.31	NS

Table 3. Efficiency of seed separation from apple core in seed extraction machine viz a viz manual operation in different cultivars of apple

Cultivar	M_1		M_2		Quantity of seed lost in seed extractor (g)	Seed damage in M_2		Seed extraction efficiency (g/h)	
	Quantity (g)	Time taken (minutes)	Quantity (g)	Time taken (minutes)	(M_1 - M_2)	(g)	(%)	M_2	M_1
Golden Delicious	15.6	51.0	14.5	3.13	1.10	0.35	2.42	277.6	18.35
Granny Smith	18.9	44.0	18.3	2.74	0.60	0.24	1.31	400.2	25.78
Gold Spur	13.2	53.0	12.5	2.16	0.70	0.25	1.99	347.2	14.94
Spartan	12.0	54.0	11.5	3.16	0.50	0.30	2.61	218.3	13.33
Red Gold	16.2	51.0	15.5	3.19	0.70	0.16	1.03	291.5	19.06
Royal Delicious	12.8	46.0	11.9	2.30	0.90	0.22	1.83	312.1	16.7
Culled Apple	15.0	61.0	14.3	2.58	0.66	0.21	1.49	333.8	14.75
$CD_{0.05}$	1.24	3.60	1.26	0.24	NS	0.06	0.40	41.69	0.10

Note: Mean feed rate of apple fruit core optimized to 22.14 kg/h with a water flow rate of 1.6 l/minute in mechanical seed separator, M_1= Seeds separated manually, M_2= Seeds separated in seed extractor pectin in the cell wall that makes it loose. The amylase treatment was however not effective as it took about 72 hours to soften the core to an extent that would facilitate easy removal of seeds in the seed separator assembly (Fig 2). Prolonged submersion of the fruit core in water may be harmful as it may hamper respiration of the seeds that ultimately leads to poor germination of the seeds (Bewley and Black 1994). Thus pre-treatment of fruit core by dipping in 1.0 per cent pectinase for 24 hours was optimized and used for softening of apple fruit core prior to seed separation through mechanical seed separator.

Different seed parameters viz length, breadth and thickness were measured which ranged between 7.11-8.53, 3.87-4.50 and 2.57-2.09 mm respectively in different cultivars. These dimensions provide important information about the fabrication of the new machinery with improved sieve size to minimize the seed losses as well as to further improve the seed extraction rate.

The suitability of mechanical seed separator for separation of seeds from the fruit core after enzymatic pre-treatment was evaluated and compared with manual separation and the data are presented in

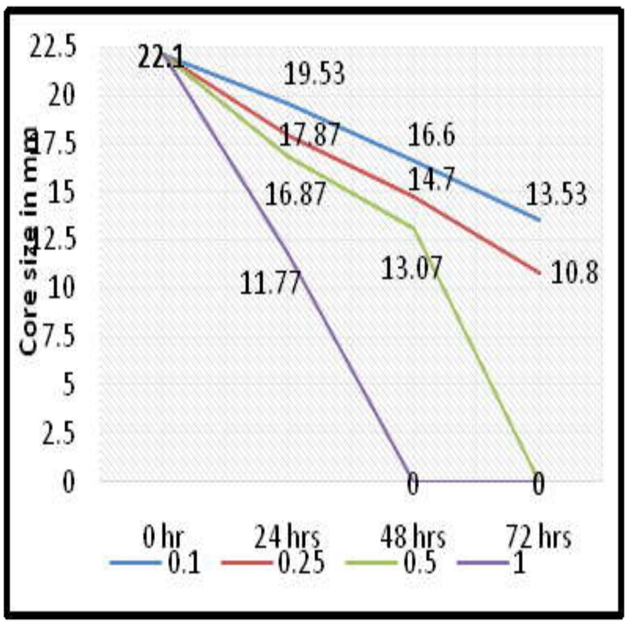

Fig 1. **Effect of different concentrations (%) of pectinase enzyme on softening of apple core at different intervals**

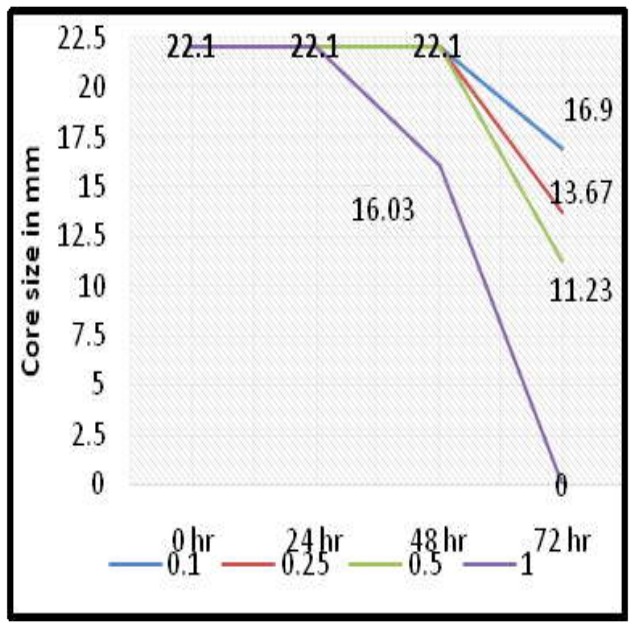

Fig 2. **Effect of different concentrations (%) of amylase enzyme on softening of apple core at different intervals**

Table 3. From 1 kg fruit core on an average 14.81 g seed was separated manually within a time period of 51.43 minutes. Thus mean seed extraction rate was recorded 17.28 g/h with the highest seed weight recovered in Granny Smith (medium grade) cultivar. On the other hand mechanical separation was found more effective as it took only 2.75 minutes to separate 14.07 g seed from 1 kg of fruit core of different cultivars. Thus average seed extraction rate through mechanical tomato seed separator worked out to be 311.53 g/h was found to be about 18 times more than that of manual seed separation. Mean feed rate of apple fruit core was optimized to be 22.14 kg/h with a water flow rate of 1.6 l/minute. During mechanical separation the seed loss and damage were found insignificant (1.81%). Thus pre-treatment of fruit core by using pectinase (1%) enzyme for 24 hours followed by seed separation through mechanical tomato seed separator was optimized for separation of seed from apple core with negligible seed damage.

Germination potential

The germination potential of the seed removed through mechanical seed separator and that separated manually from apple fruit core was found statistically at par (89.9 and 89.3%) while pomace seeds (seeds separated from apple pomace left after juice extraction) exhibited lowest seed germination (65.3%) (Table 4). Poor seed germination in seeds separated from the pomace may be attributed to crushing and pressing of seeds during extraction of juice in commercial processing plants. There was no significant difference

Table 4. Effect of method of seed separation on seed germination, seedling length, seedling dry weight, seed vigor index (I and II) and seed germination index in apple seeds

Seed type	Seed germination (%)	Seedling length (cm)	Seedling dry weight (mg)	SVI-I	SVI-II	GI
S_1 (core seeds)	89.3	13.3	0.25	1190.1	22.5	18.0
S_2 (core seeds)	89.9	13.7	0.25	1227.6	22.7	18.3
S_3 (pomace seeds)	65.3	13.6	0.26	882.1	15.7	18.2
$CD_{0.05}$	1.60	0.18	NS	12.972	3.39	NS

S_1= Seeds separated manually from apple core, S_2= Seeds of apple core removed through tomato seed separator, S_3= Seeds separated from apple pomace left after juice extraction, GI= Seed germination index, SVI= Seed vigor index

in seedling length and seedling dry weight of the seeds separated manually or by using mechanical separator. Seed vigour index (SVI-I and SVI-II) ranged between 882.1-1227.6 and 15.7-22.7 respectively. Seeds separated mechanically had highest SVI-I (1227.6) followed by the seeds separated manually (1190.1) and was minimum for pomace seeds (882.1). Similar trend was followed in SVI-II with maximum SVI-II (22.7) in mechanically separated seeds and minimum for pomace seeds (15.7). Germination index of seeds separated by different methods showed a statistically non-significant difference. These parameters indicate that there was no effect of the developed technology on the germination potential of seeds, speed of germination (GI) and vigour of seedling.

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