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Development of juice extraction process for pomegranate (*Punica granatum*): Evaluation and physicochemical aspects

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India is the largest producer of pomegranates (*Punica granatum* L.) fruit globally with total production of 2329.00 thousand MT (NHB 2019-20). The pomegranate fruits are famous worldwide and are consumed fresh or used to prepare fresh juice, drinks, wines, jam and jelly, and coloring beverage products and flavoring (Mousavinejad *et al*. 2009). Consumption of pomegranate juice has shown several health benefits like reductions of systolic blood pressures in hypertensive patients, a decrease of standard carotid artery intima-media thickness, attenuation of myocardial ischemia, and the lipid profile improvement of diabetic patients (Rosenblat *et al*. 2006). Traditionally it is used as a medical antidote, and its flowers, bark, and leaves contain antimicrobial bioactive compounds. The foremost challenge in pomegranate juice extraction is the mechanical peeling of the fruit. It is time-consuming and irritating as the hands get stained due to polyphenols and oxidative enzymes containing peel (Dhinesh *et al*. 2016). Hence, the present investigation on developing and evaluating the novel developed pomegranate juice extractor is a prime requirement to the growers and entrepreneurs.

The freshly matured pomegranate fruits (cv. Bhagwa) were sourced from Junagadh, Gujarat, India, grown during *kharif* 2017. The pomegranate juice extractor was developed at the workshop of Agricultural Process Engineering Departrment, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh during 2017.

Development of pomegranate extractor: The pomegranate juice extractor was developed based on the engineering properties of the cv. Bhagwa pomegranate (Jithender *et al*. 2017). The essential components attached with the extractor were feeding chute, carrier roller, surgical doctors' blade, crushing roller, waste outlet, juice collection platform, juice filter, driving mechanism, motor, and speed controller (Fig 1). The feeding chute is an essential part, where the fruit is fed into the carrier roller groove through gravity. The two identical carrier and crushing rollers were made of Teflon. The juice collecting platform with the filter was made of stainless-steel material at the middle of the platform.

Operation of juice extractor: Initially, in first stage, the fresh pomegranate fruits were passed through feed chute and was passed to carrier roller grooves, eventually passed to sharp cutting blades. In second stage, the cut-fruits passes to crushing rollers, were the crushing of arils and separation of peels take place in outlet. Finally, the extracted juice was collected and properly filtered.

Performance evaluation of the juice extractor: The carrier roller speed was considered for evaluating the developed juice extractor. The performance evaluation parameters such machine capacity, extraction losses, extraction efficiency was calculated by the equation reported by Olaoye (2011) and Nickhil *et al.* (2020).

Physico-chemical analysis: The pH of the pomegranate juice was measured using digital pH meter (Model: Adwa AD8000) in triplicates. The digital hand-held refractometer (Model: PAL-1; Make: Atago, Japan) was used for measuring TSS content. The total sugar content was estimated following the phenol-sulphuric acid method described by Shahbaz *et al.* (2014). The total phenolic content was determined by using the Folin-Ciocalteu reagent (CR) assay according to the method of Mousavinejad *et al.* (2009). Total flavonoid content was measured as described by Yang *et al.* (2009).

Sensory analysis: The sensory analysis was carried out by ten panelists, according to the previous method reported by Castro-Vazquez et al. (2009).

Statistical analysis: Statistical analysis was carried out using response surface methodology to optimize the operating conditions of the developed juice extractor (Table 1) using Design Expert Version 11.0.

Optimization of the developed pomegranate juice extractor: The optimization of the developed pomegranate juice was selected based on the variation of the carrier roll speed with maximum machine capacity and extraction

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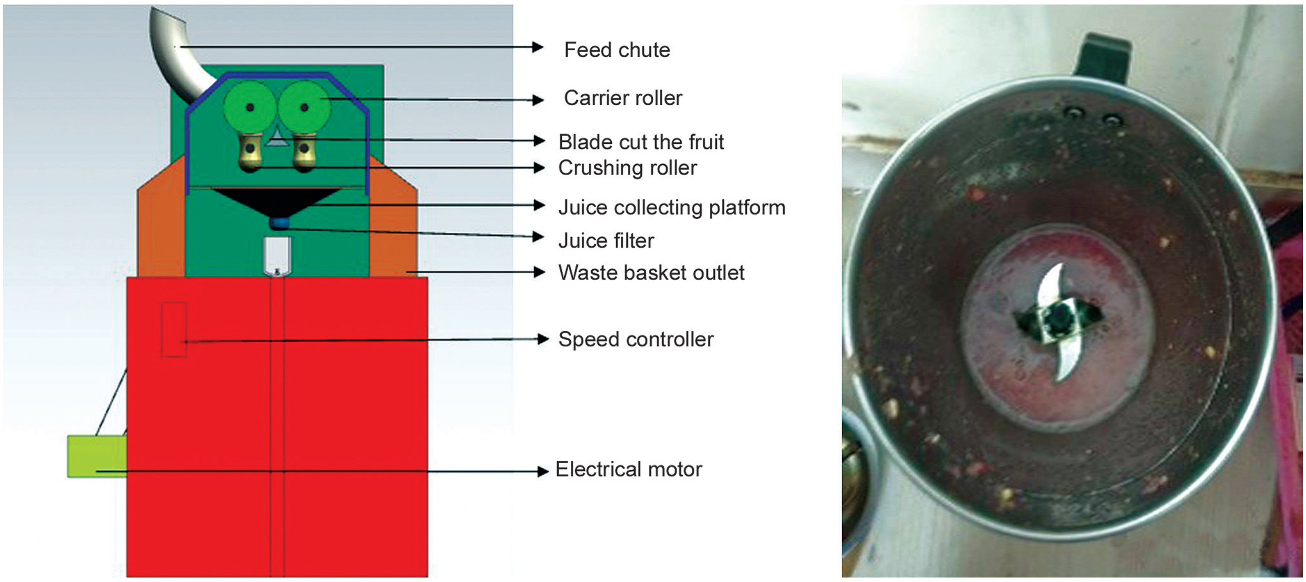

Fig 1 Isometric view of pomegranate juice extractor and electrical mixer.

Table 1 Experimental values of pomegranate juice extractor

Runs	Process variable	Responses		
	Factor 1(Carrier roller speed (rpm) A: A	Machine capacity (kg/h)	Extraction efficiency (%)	Extraction losses (%)
1	7.5	114	70	30
2	5	68	55	45
3	15	357	75	25
4	5	67	55	45
5	12.5	293.5	80	20
6	10	230	88	12
7	15	357	75	25

efficiency with minimum extraction loss. The effect of carrier speed on the machine capacity, extraction efficiency and extraction losses of the juice. Table 2 shows empirical model first order equation of the performance characteristics of pomegranate juice extraction. Based on the highest and lowest machine capacity, the carrier roller speed (10 rpm) was optimized to evaluate the physicochemical aspects of the juice. The juice yield in the developed juice extractor and mixer were 98.3 % and 48.20 %. Also, the juice extraction cost (₹ 0.2/ kg) and machine capacity (357 kg/h) were highest in extractor machine compared to mixer.

Machine capacity (kg/h): The carrier roller speed (15 and 5 rpm) showed 357 kg/h of maximum and 68 kg/h of minimum machine capacity in extracting pomegranate juice. The feed rate was increased with increase in RPM due to this effect; the machine capacity was increased. The effect of varied carrier roll speed on machine capacity was statistically analyzed, and the result obtained to be significant ($P<0.05$) with a R^2 =0.99. The obtained results were found similar to the experiments conducted by Aviara *et al*. (2013).

Extraction efficiency (%): The extraction efficiency was found to be highest (88%) and lowest (55%) at the carrier speed of 10 and 5 rpm. Due to an increase in speed, the extraction time is reduced, resulting in inadequate crushing pressure on the fruit resulting in lesser extraction efficiency. The type of fruit also affects the machine's extraction efficiency, which seems to indicate that extraction efficiency is dependent on the potential juice content of fruits. However, it could also depend on their texture/hardness. The extraction efficiency results were in line with Olabisi and Adelegan (2015) for citrus fruit juice.

Extraction losses (%): The evaluation conducted resulted that at carrier speed (5 and 10 rpm), the maximum and minimum loss was 88% and 12%, respectively. The effect of varied carrier roll speed on extraction losses was statistically analyzed, and the result obtained to be significant ($P<0.05$) with a R^2=0.99. This result is similar to the extraction loss obtained from the evaluation of multi-juice extractor with extraction loss of 2–20% in case of Olaniyan (2010) and Adanu *et al.* (2015).

Physico-chemical analysis of extracted juice: The *p*H of continuous extractor juice and electrical mixer juice was 3.32 ± 0.025 and 3.94 ± 0.046, respectively, with both acidic juices. The average TSS obtained were 19.13 ± 0.126 and 16.5 ± 0.25 °Brix, respectively, in extractor and mixer. The

Table 2 Development of empirical model first order equation of the performance characteristics of pomegranate juice extraction

Parameter	Empirical model equation
Machine capacity (Kg/h)	-127.48 + 39.86× (carrier speed) -0.47 × (carrier speed) ^{2}
Extraction efficiency (%)	-10.55 + 16.70 × (carrier speed) - 0.73 × (carrier speed) ^{2}
Extraction losses (%)	110.55 -16.70 × (carrier speed) +0.73 × (carrier speed) ^{2}

sweetness and flavor in the fruit and a decrease in juice acidity and tannin concentration causes the increase in the TSS content (Zarei *et al*. 2011). The lower value of TSS in electrical mixer juice might be due to the chances of crushing the seed during grinding in mixer/grinder in the conventional method. As in previous cases here, due to the crushing of seed during extraction in the conventional method, the value of titratable acidity (0.581±0.01%) in the conventionally extracted juice was found less compared to pomegranate extractor (0.70±0.04%). The average total sugar of continuous extractor juice and electrical mixer juice was found to be 16.80±0.09% and 12.81±0.042%, respectively, Similar to the TSS, the total sugar content of the juice extracted by developed extractor juice was found more than that of conventionally extracted juice, here also the lower value of total sugar in conventionally extracted juice might be due to a slight number of seed, crushed during extraction. Total flavonoid content in pomegranate juice of the electrical mixer (58.2 mg CE/100 mL) was greater than continuous juice extractor (22.2 mg CE/100 mL). The average total phenolic acid of developed extractor juice and juice extracted with the mixture was found to be 0.209±0.008% and 0.115±0.005%, respectively.

Sensory evaluation: The results of the average consumer acceptability studies indicate significant differences by the panelists between developed extractor and mixer extracted juice in terms of color (9 vs. 7), odor (8.5 vs. 7), acidity (8 vs. 7), sweetness (9 vs. 7), flavor (9 vs. 6) and overall acceptability (9 vs. 7), respectively. The panelists found the developed extracted juice with good flavor twice than juice extracted with electrical mixer juice. The overall acceptability was more in the case of a developed type extractor than an electric mixer.

SUMMARY

The pomegranate (*Punica granatum* L.) consumption is tremendously increasing due to the development of diversified value-added products and its health benefit among all age groups of consumers. The initial stage in extracting the pomegranate fruit juice is a very drudgery and time-consuming process. To meet these difficulties, the pomegranate juice extractor was developed consisting of feed chute, carrier roller, crushing roller and juice collecting platform with filter. The performance evaluation of the developed juice extractor resulted 357 kg/h of machine capacity, 88% of extraction efficiency and 12% of extraction losses. The quantitative analysis after juice extraction showed enhanced results in *p*H (3.32), TSS (19.13) total phenol (0.209 %) and the total flavonoids content (22.2 mg CE/100 mL).

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