Physicochemical Evaluation of Apple Pomace from Different Apple Varieties as Affected by Different Extraction Methods

Imtiaz Ghafoor[1*], Tahseen Fatima Miano[2], Asif Irshad[3], Nisar Ahmed Gichki[2], Jaber Baloch[1], Abid Ali[1], Adeena Choudhri[2], and Mohammad Shakir[4]

[1]Food Department Balochistan, Quetta, Pakistan

[2]Institute of Food Sciences and Technology, Sindh Agriculture University, Tandojam, Hyderabad, Pakistan

[3]Department of Food Preservation, Technical Wing of Colleges, Higher & Technical Education Department, Balochistan, Pakistan

[4]Department of Food Technology, Balochistan Agriculture College Quetta, Balochistan

*Corresponding Author: **Imtiaz Ghafoor**

ABSTRACT

The apple (*Malus domestica* L.) is an ancient and widely cultivated fruit in temperate climates, rich in dietary fiber, minerals, vitamins, and various nutrients. Its peel, core, and pulp contain high levels of phenolic compounds and phytonutrients, contributing to a reduced risk of cancers, cardiovascular diseases (CVD), asthma, and diabetes. The present study aimed to assess apple waste and analyze the physicochemical properties of apple pomace. Two apple varieties, Gaja and Golden Delicious, were studied and two extraction methods were used i.e., manual (squeezing) and mechanical (juicer/blinder). The results revealed that the Gaja variety has higher juice content (55.00% manual, 53.00% mechanical) compared to the golden variety (46.00% manual, 44.00% mechanical). Additionally, the Golden Delicious showed a slightly higher peel percentage and total waste for both extraction methods. The pH values ranged from 3.91 to 4.04, with the Gaja variety generally having slightly higher values. Ash content was comparable between the varieties and extraction methods. The TSS was higher in the Golden Delicious variety, especially in the mechanical extraction method (i.e., 18.67 ^{o}Brix). Fiber and protein content varied among the apple varieties and extraction methods, with the mechanical method generally yielding slightly higher values. Titratable acidity was consistent across both varieties. Moisture content was observed to be higher in the Gaja variety, particularly in the manual extraction method. Overall, the Gaja variety was favored for its higher juice content, while Golden Delicious had advantages in size and certain physicochemical properties like fiber, protein, TSS, and ash.

Keywords: Apple, Apple Pomace, Physicochemical properties, Extraction methods, Variety comparison

INTRODUCTION

The apple (*Malus domestica* L.) is one of the most consumed fruits worldwide, both as fresh and processed products. To meet the global demands for juices, juice concentrates, and cider, 11.6 million tons of apples are processed (Fernandes *et al.*, 2019), resulting in 30% of the product becoming waste. Globally, these wastes may represent up to 4 million tons per year of apple pomace (Martins Costa *et al.*, 2022), consisting of pulp, skins, seeds, and stalks of the fruit (Kammerer *et al.*, 2014).

Apple pomace is a heterogeneous substance primarily composed of skin and flesh (95%), with traces of seeds (2-4%) and stems (1%). Apple pomace contains a wide range of nutrients, despite variations in concentration. It is a good source of phytochemicals and contains significant amounts of carbohydrates as well as small amounts of proteins, vitamins, and minerals (Shashi *et al.*, 2008). The carbohydrates found in apple pomace are primarily composed of insoluble sugars, such as cellulose (127.9 g/kg DW), hemicellulose (7.2 to 43.6 g/kg DW), and lignin (15.3 to 23.5 g/kg DW), along with simple sugars like glucose (22.7%), fructose (23.6%), and galactose (6% to 15%) (Dhillon *et al.*, 2013). Apart from carbohydrates, several minerals like P (0.07% to 0.076%), Ca (0.06% to 0.1%), Mg (0.02% to 0.36%), and Fe (31.8 to 38.3 mg/kg, dry weight basis) were also found in apple pomace. Apple pomace is further distinguished by a high percentage of polyphenols (31% to 51%), particularly cinnamate esters, dihydrochalcones, and flavonols (Will *et al.*, 2006). Moreover, it has been demonstrated that apple pomace contains a wide range of naturally occurring antioxidants, including phloridzin, quercetin glycosides, and other phenolic components with potent antioxidant activity (Lu and Foo, 2000; Schieber *et al.*, 2002). Therefore, apple pomace is of great nutritional value, providing health benefits. Several studies indicated that apple pomace not only helps in the prevention of constipation and hypertension but also can scavenge certain harmful substances in the human body such as free radicals (Shashi *et al.*, 2008).

Given its nutritional value, apple pomace has found utilization as a functional ingredient in various food products (Gómez and Martinez, 2018). Its incorporation enhances the dietary fiber content and health-promoting properties of bakery products, extruded foods, meat products, confectionery items, and dairy foods. Additionally, it serves as a substrate for the development of alcoholic beverages and edible mushrooms, contributing to product quality and nutritional value (Lyu *et al.*, 2020).

Understanding the physicochemical properties of apple pomace from different varieties and the impact of various extraction methods is crucial for optimizing its utilization in different food products. Thus, the present study aims to contribute to this knowledge, facilitating the efficient utilization of apple pomace as a valuable resource in the food industry.

Materials and methods

Sample collection

Two varieties (Gaja and Golden Delicious) of apple fruits were purchased from the local market of Tandojam city of Hyderabad, Pakistan.

Extraction procedures of apple juice

1. Manual method of apple juice extraction

300 g of apple samples were weighed. These weighed samples were washed and cleaned with tissue paper. Weighed and washed apple samples were kept in the deep freezer to freeze. Took out freeze samples from the deep freezer and kept it for 2 to 3 hours to defrost. Put the sample in the muslin cloths and squeeze by hand with force. Separately juice, peel, and waste materials were measured and weighed.

2. Mechanical method of apple juice extraction

300 g of apple samples were weighed. These weighed samples were washed and cleaned with tissue paper. Samples were put into the juicer blender. Separately juice, peel, and waste materials were measured and weighed.

Physico-chemical analysis of apple pomace

The proximate composition analysis of samples, including moisture (%), protein (%), ash (%), TSS (°Brix), pH value, crude fiber (%), and titratable acidity (%) contents was determined using (AOAC, 2016).

Statistical analysis

The data collected from the research were statistically analyzed according to the statistical procedure of analysis of variance two-way (ANOVA), by using Statistix 8.1 software.

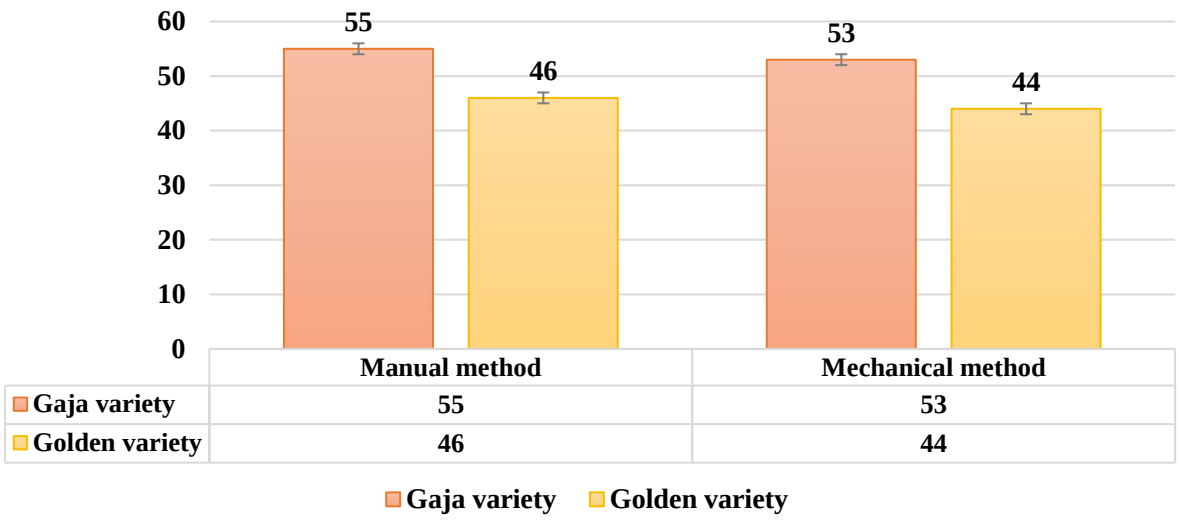
Results and Discussion

Juice (%) of apple varieties

The results regarding Juice (%) of apple varieties as influenced by different extraction methods are shown in Figure 1. The statistical analysis showed significant variation ($P \leq 0.05$) in juice content among different apple varieties. The maximum juice % was noted in the Gaja variety (55.00%) in the manual method, followed by the Gaja variety through the mechanical method (53.00%), Golden Delicious manual and mechanical method i.e., 46.00% and 44.00%, respectively. The results are further confirmed by Nadulski *et al.* (2014) who reported that the maximum apple juice was (54.24%), while the minimum apple juice was (42.24%). Similarly, the study of Sharma *et al.* (2015) showed that the maximum apple juice was (59.17%), while the minimum apple juice was (53.14%), respectively. The variations may be due to extraction

methods or harvesting time.

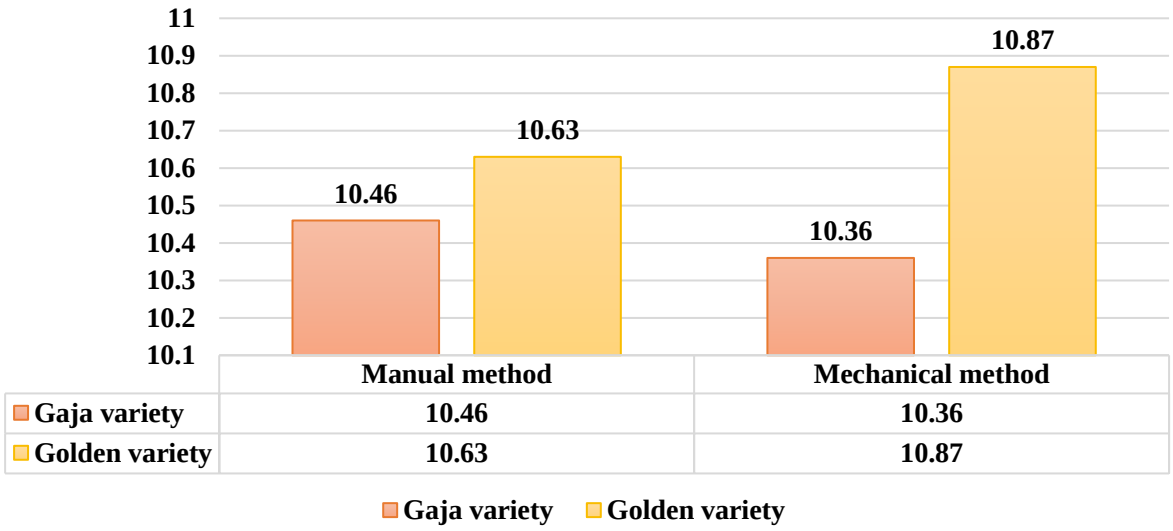
Fig. 1 Juice (%) of apple varieties as influenced by different extraction methods



Peel (%) of apple varieties

The results regarding the peel (%) of apple varieties as influenced by different extraction methods are shown in Figure 2. The statistical analysis showed significant variation ($P \leq 0.05$) in juice content among different apple varieties. The maximum peel % was observed in the Golden Delicious variety (10.87%) in the mechanical method followed by the Golden Delicious manual method (10.63%) while the lowest results were recorded in the Gaja variety mechanical method (10.36%). The results are further confirmed by Martínez-Ladrón de Guevara *et al.* (2016) who reported that the maximum apple peel was (15.14%), however minimum apple peel was (10.75%). Similarly, the study of Francini and Sebastiani, (2013) revealed that the maximum apple peel was (14.46%), while the minimum apple peel was (11.15%). The variation may be because the peel comprises only a small percentage of the entire fruit weight, its importance as a donor of phenolic is disputable.

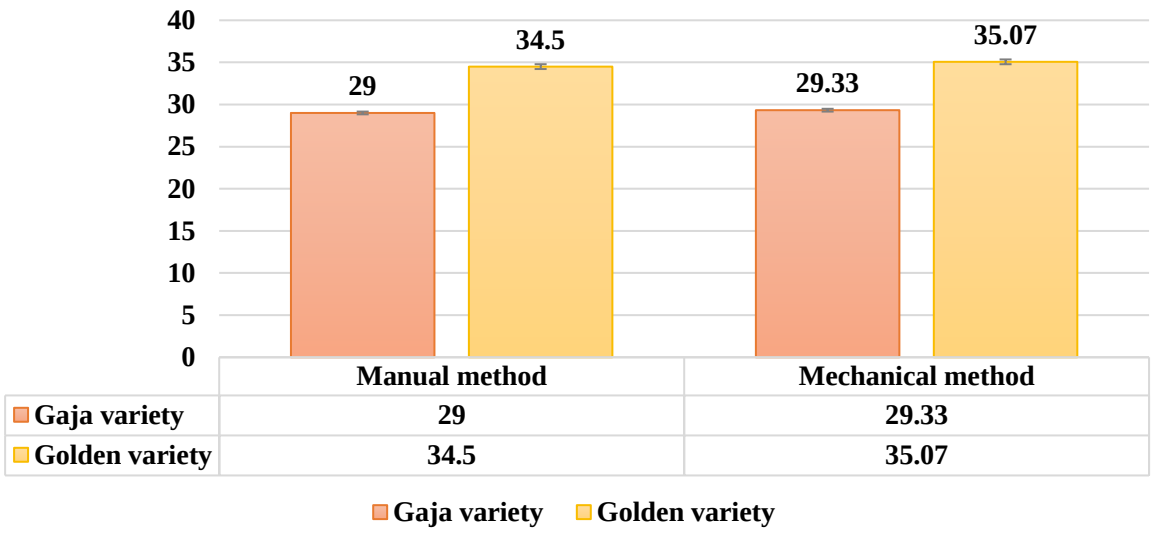
Fig. 2 Peel (%) of apple varieties as influenced by different extraction methods



Total waste (%) of apple varieties

The results regarding the total waste (%) of apple varieties as influenced by different extraction methods are shown in Figure 3. The statistical analysis showed significant variation ($P \leq 0.05$) in juice content among different apple varieties. The maximum total waste % was noted in the Golden Delicious (35.07%) mechanical method, followed by the Golden Delicious manual method (34.50%) while minimum results were recorded in the Gaja variety manual method (29%). The observed results are confirmed by Okruhlicova *et al.* (2002) who reported that the maximum total waste was (41.15%), while the minimum total waste was (32.14%). The results were also compared with Lin *et al.* (2006) who reported that the maximum total waste was (42.15%), while the minimum total waste was (32.14%). The observed variations may be due to the extraction methods or water present in the apple.

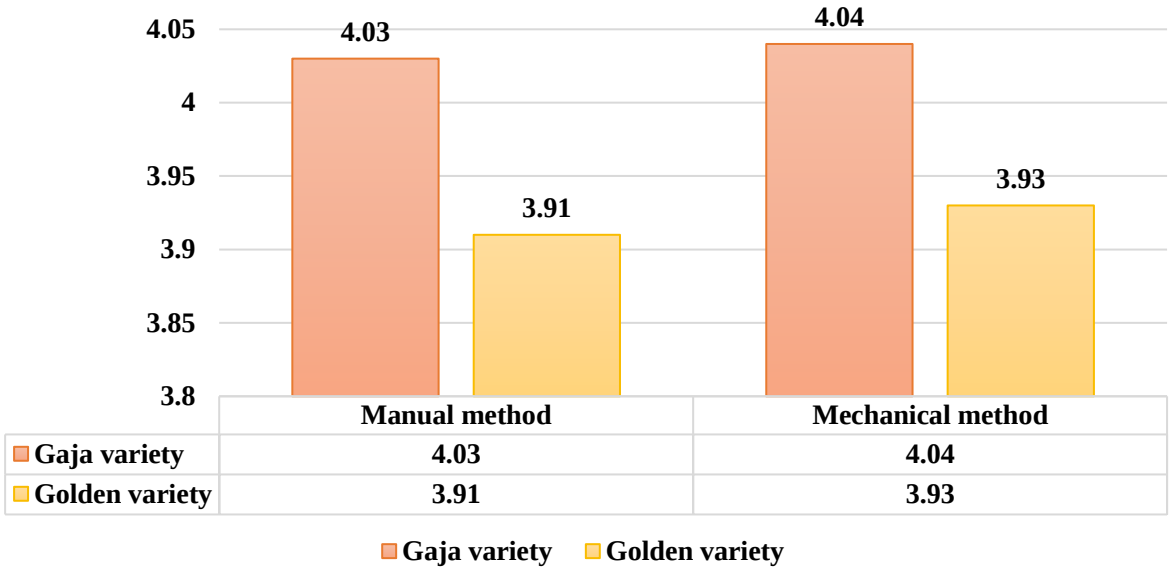
Fig. 3 Total waste (%) of apple varieties as influenced by different extraction methods



pH value of apple pomace

The results regarding the pH value of apple pomace as influenced by different extraction methods are shown in Figure 4. The statically analyzed result for pH value in apple pomace significantly varied at ($P \leq 0.05$). The maximum pH value was noted in the Gaja variety (4.04) mechanical method, followed by the Gaja variety manual method (4.03) while the minimum pH value was noted in the Golden Delicious manual method i.e., 3.91. The results are further confirmed by Venkatachalam *et al.* (2018) who observed that the maximum pH value of apple pomace was (6.8±0.4), while the minimum pH value was (3.0±0.3). A similar study by Giryn *et al.* (2004) showed that the maximum pH value of apple pomace was (3.77), while the minimum pH value of apple pomace was (3.39). The variation in pH value may be due to the variety, location of apple harvest, harvest time method of extracting, and further processing of juices.

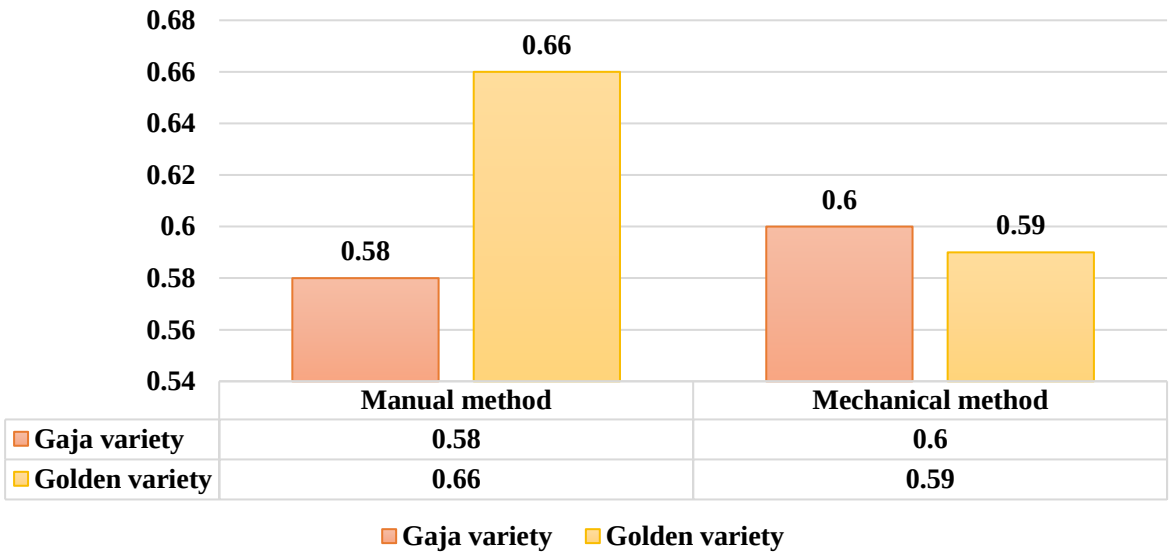
Fig. 4 pH value of apple pomace as influenced by different extraction methods



Ash (%) of apple pomace

The results regarding the ash (%) of apple pomace as influenced by different extraction methods are shown in Figure 5. The statically analyzed result for ash % in all treatments of apple pomace significantly varied at ($P \leq 0.05$). The maximum ash % was noted in the Golden Delicious (0.66%) manual method, followed by the Gaja variety mechanical method 0.60%, while the minimum ash % was recorded in the Gaja variety manual method i.e., 0.58%. The results are further confirmed by Jayaprakasha and Patil, (2007) who reported that the maximum ash % was (0.61%), while the minimum ash % was (0.57%) in apple pomace. Similarly, the study of Eisele and Drake, (2005) reported that the maximum ash % was (0.39%), while the minimum ash % was (0.12%). The variation may be due to the quantity of minerals present in the apple.

Fig. 5 Ash (%) of apple pomace as influenced by different extraction methods

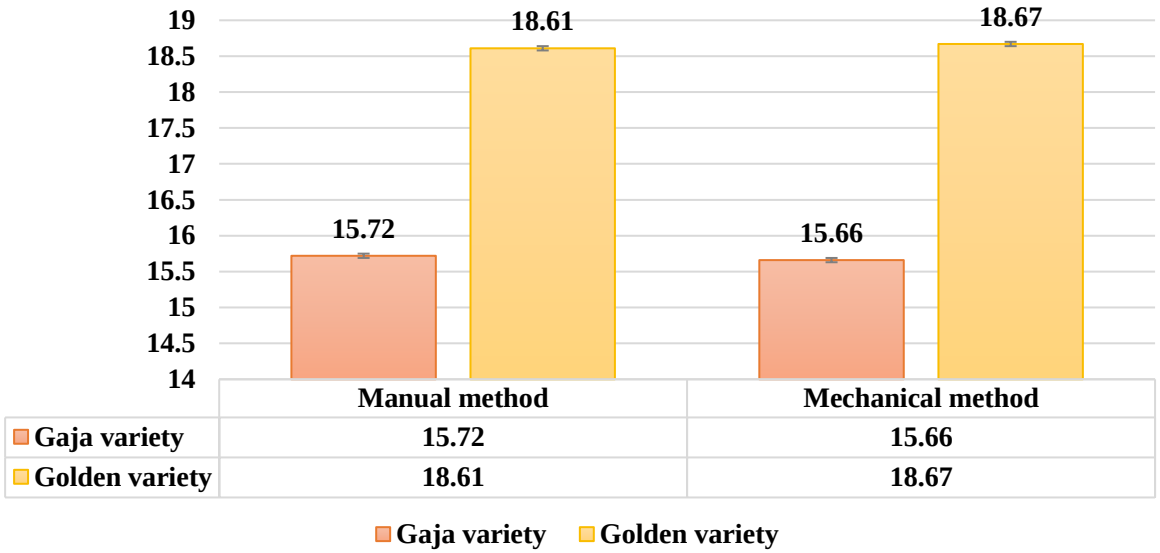


	Manual method	Mechanical method
Gaja variety	0.58	0.6
Golden variety	0.66	0.59

Total soluble solids (°Brix) of apple pomace

The results regarding total soluble solids (°Brix) of apple pomace as influenced by different extraction methods are shown in Figure 6. The statically analyzed results for total soluble solids in all treatments of apple pomace significantly varied at ($P \leq 0.05$). The maximum TSS was noted in Golden Delicious (18.67 °Brix) in the mechanical method, followed by Golden Delicious manual method (18.61 °Brix), while minimum TSS was recorded in the Gaja variety mechanical method i.e., 15.66 °Brix. The results are compared with Eisele and Drake, (2005) who reported that the maximum total soluble solids were (21.62 °Brix), while the minimum total soluble solids were (10.26 °Brix) depending on the apple variety. The total soluble solids of apple fruit increased gradually with increasing storage durations. The total soluble solids could be attributed to the breakdown of starch or the hydrolysis of cell wall polysaccharides.

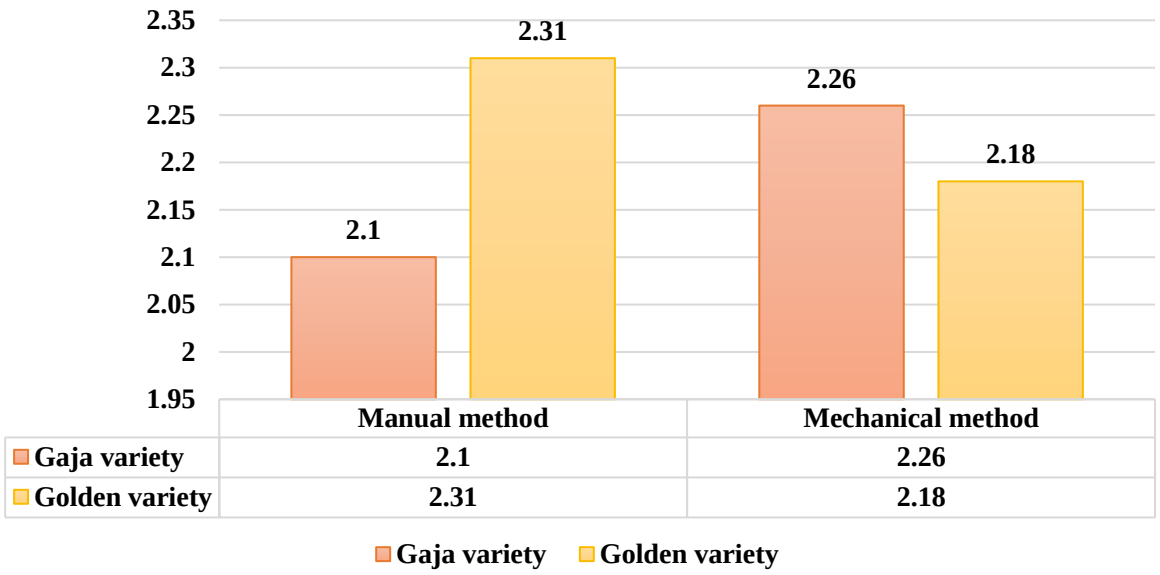
Fig. 6 Total soluble solids (°Brix) of apple pomace as influenced by different extraction methods



Protein (%) of apple varieties

The results regarding protein (%) of apple pomace as influenced by different extraction methods are shown in Figure 7. The statically analyzed result for protein in all treatments of apple pomace significantly varied at ($P \leq 0.05$). The maximum protein % was noted in the Golden Delicious (2.31%) manual extraction method, followed by the Gaja variety mechanical method (2.26%), while the minimum protein % was recorded in the Gaja variety manual method i.e., 2.10%. The results are confirmed by Okokon and Okokon, (2019) who reported that the maximum protein % was (1.85%), while the minimum protein % was (1.14%) in apple pomace. The variation may be due to phenolic compounds ranging from anthocyanin or carotenoid pigments to tannins are usually far less than 1% or 2.50%.

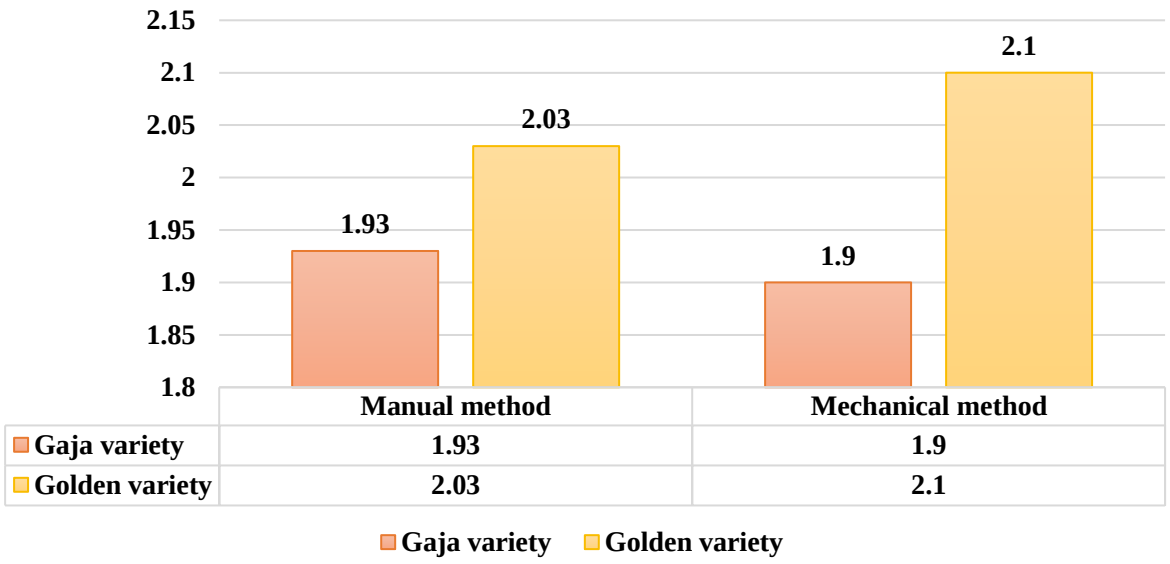
Fig. 7 Protein (%) of apple pomace as influenced by different extraction methods



Fiber (%) of apple pomace

The results regarding fiber (%) of apple pomace as influenced by different extraction methods are shown in Figure 8. The statically analyzed result for fiber in all treatments of apple pomace significantly varied at ($P \leq 0.05$). The maximum fiber % was noted in the Golden Delicious (2.10%) mechanical method, followed by the Golden Delicious manual method (2.03%), while the minimum fiber % was recorded in the Gaja variety mechanical method i.e., 1.90%. The results are further confirmed by Lisičar *et al.* (2017) who reported similar reports as observed by the present study. Ciriminna *et al.* (2016) recorded the maximum fiber % as 2.24% and minimum as 2.19% in apple pomace from different apple varieties. The variation may be due to different varieties having different fibers.

Fig. 8 Fiber (%) of apple pomace as influenced by different extraction methods

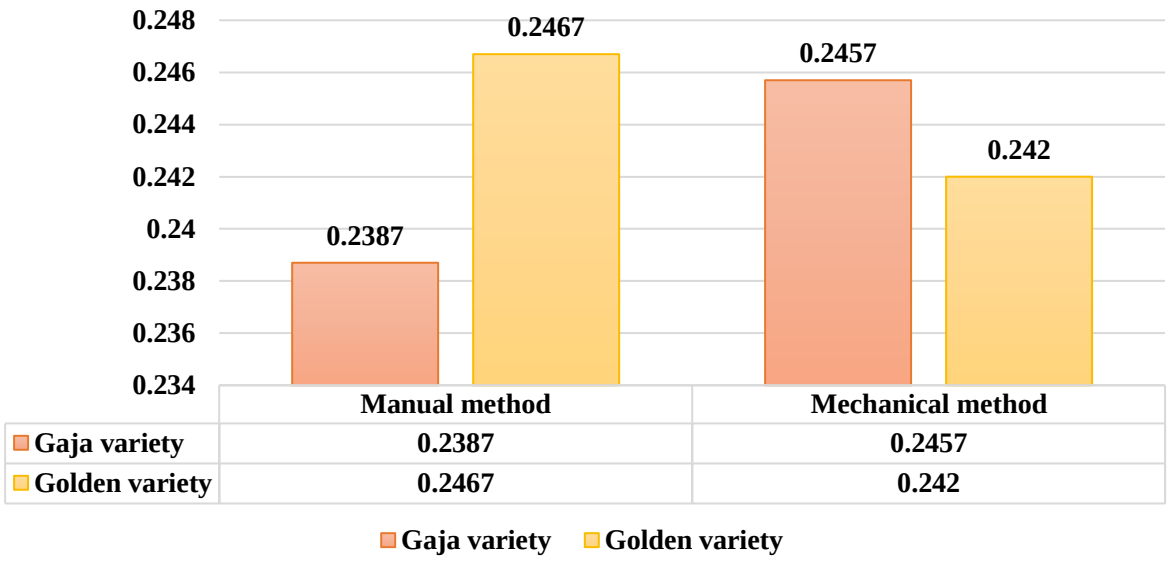


	Manual method	Mechanical method
Gaja variety	1.93	1.9
Golden variety	2.03	2.1

Titratable acidity (%) of apple pomace

The results regarding titratable acidity (%) of apple pomace as influenced by different extraction methods are shown in Figure 9. The statically analyzed result for titratable acidity in all treatments of apple pomace significantly varied at ($P \leq 0.05$). The maximum titratable acidity was observed in Golden Delicious (0.2467 %) through the manual method, followed by the Gaja variety through the mechanical method (0.2557%), while minimum results were noted in Gaja variety through the manual method i.e., 0.2387%. The results are further associated with the report that the maximum titratable acidity was (0.251), while the minimum was (0.240). The variation may be due to malic and citric acids making the major contribution to the acidity of the apple.

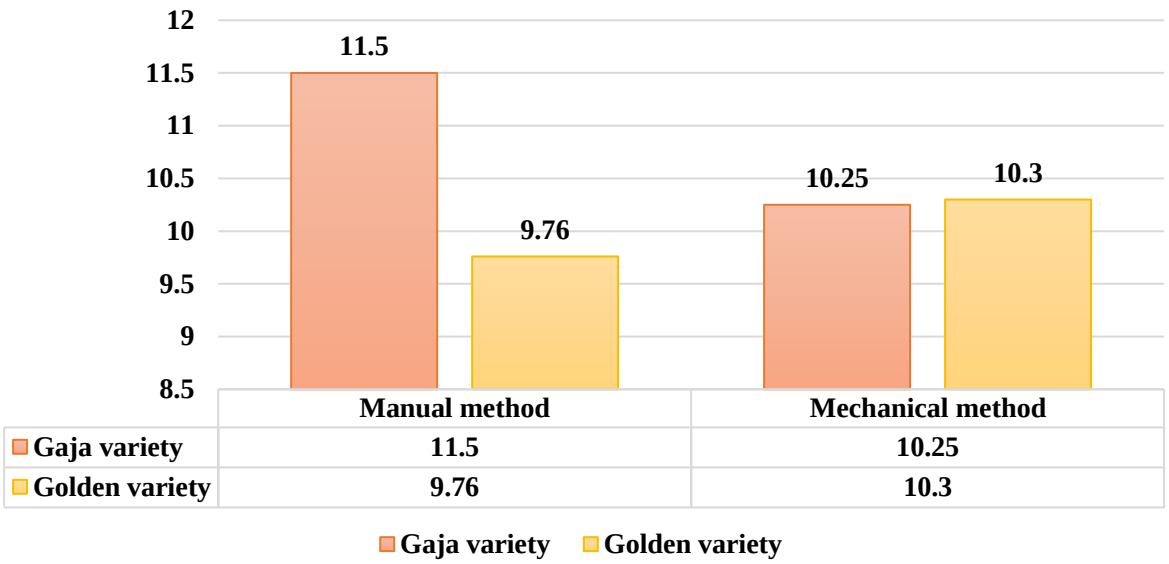
Fig. 9 Titratable acidity (%) of apple pomace as influenced by different extraction methods



Moisture (%) of apple pomace

The results regarding moisture (%) of apple pomace as influenced by different extraction methods are shown in Figure 10. The statically analyzed result for moisture in all treatments of apple pomace significantly varied at ($P \leq 0.05$). The maximum moisture % was observed in the Gaja variety (11.50%) in the manual method, followed by Golden Delicious through the mechanical extraction method (10.30%), while minimum moisture content was observed in Golden Delicious through the manually extracted method i.e., 9.76%. The results further correlate with the study of Olaniran *et al.* (2019) who reported the maximum moisture (9.21%) in apple pomace while the minimum moisture recorded was (8.44%). The variation may be due to the variety, environmental temperature, and juice processing methods.

Fig. 10 Moisture (%) of apple pomace as influenced by different extraction methods



Conclusion

The present study investigated the physicochemical properties of apple pomace obtained from Gaja and Golden Delicious apple varieties using manual and mechanical extraction methods. The findings suggest that the Gaja variety yielded a higher juice content compared to Golden Delicious. Golden Delicious had a slightly higher peel percentage and total waste for both extraction methods. pH values were acidic with minimal variation between varieties and extraction methods. Ash content showed no significant difference between varieties or extraction methods. Golden Delicious exhibited higher TSS, especially with mechanical extraction. Fiber and protein content varied with the mechanical method generally yielding slightly higher values. Titratable acidity remained consistent across both varieties. The Gaja variety had higher moisture content, particularly with manual extraction. In conclusion, Gaja appears favorable for juice production due to its higher juice yield. However, Golden Delicious offers advantages in terms of size and specific physicochemical properties like fiber, protein, TSS, and ash content. The choice of variety and extraction method may depend on the desired end product and its intended use.

Acknowledgment

The authors are grateful to the Institute of Food Sciences and Technology, Sindh Agriculture University Tandojam for providing the required facilities to conduct the research.

Conflict of Interest

The authors declare no conflict of interest.

Authors' Contribution

The research was conducted by **Imtiaz Ghafoor**. **Tahseen Fatima Miano** supervised the research. **Asif Irshad** created the graphs and removed the plagiarism of manuscript. **Nisar Ahmed Gichki**, **Jaber Baloch**, **Abid Ali**, **Adeena Choudhri**, and **Mohammad Shakir** contributed to experiments, data analysis, and manuscript writing.

Authors:

Imtiaz Ghafoor
Assistant Food Controller at Food Department Balochistan, Quetta Pakistan.

Tahseen Fatima Miano
Ph.D. Assistant Professor at Institute of Food Sciences and Technology, Sindh Agriculture University, Tandojam, Hyderabad, Pakistan.

Asif Irshad
Lecturer of Food Preservation at the Technical Wing of Colleges, Higher & Technical Education Department, Balochistan, Pakistan.

Nisar Ahmed Gichki
Food Safety Officer at Balochistan Food Authority, Quetta Pakistan.

Jaber Baloch
Deputy Director Admin at Food Department Balochistan, Quetta Pakistan.

Abid Ali
Assistant Food Controller at Food Department Balochistan, Quetta Pakistan.

Adeena Choudhri
Postgraduate from the Institute of Food Sciences and Technology, Sindh Agriculture University, Tandojam, Hyderabad, Pakistan.

Mohammad Shakir
Lecturer of Food Technology at Balochistan Agriculture College, Quetta Pakistan.

References

AOAC (2016). Official methods of analysis of AOAC international. 20th Edition. Association of the Official Analytical Chemists, Gaithersburg.

Ciriminna, R., A. Fidalgo, R. Delisi, L.M. Ilharco, & M. Pagliaro (2016). Pectin production and global market. Agro Food Ind. Hi-Tech, 27(5), 17-20.

Dhillon, G.S., S. Kaur, & S.K. Brar (2013). Perspective of Apple Processing Wastes as Low-Cost Substrates for Bioproduction of High Value Products: A Review. Renew. Sustain. Energy Rev. 27, 789–805.

Eisele, T.A., & S.R. Drake (2005). The partial compositional characteristics of apple juice from 175 apple varieties. Journal of food composition and analysis, 18(2-3), 213-221.

Fernandes, P.A.R., C. Le Bourvelle, C.M.G.C Renard, F.M. Nunes, R. Bastos, E. Coelho, D.F. Wessel, M.A. Coimbra, & S.M. Cardoso (2019). Revisiting the chemistry of apple pomace polyphenols. Food Chem. *294*, 9–18.

Francini, A., & L. Sebastiani (2013). Phenolic compounds in apple (Malus x domestica Borkh.): compounds characterization and stability during postharvest and after processing. Antioxidants, 2(3), 181-193.

Giryn, H., B. Szteke, & K. Szymczyk (2004). Effect of technological process and storage on the content of organic acids in concentrated apple juices. Food. Science. Technology. Quality, 11(2), 92-107.

Gómez, M., & M.M. Martinez (2018). Fruit and Vegetable By-Products as Novel Ingredients to Improve the Nutritional Quality of Baked Goods. Crit. Rev. Food Sci. Nutr. 58, 2119–2135.

Jayaprakasha, G.K., & B.S. Patil (2007). In vitro evaluation of the antioxidant activities in fruit extracts from citron and blood orange. Food Chemistry, 101(1), 410-418.

Kammerer, D.R., J. Kammerer, R. Valet, & R. Carle (2014). Recovery of polyphenols from the by-products of plant food processing and application as valuable food ingredients. Food Res. Int. 65, 2–12.

Lin, H., K. Ogawa, I. Imanaga, & N. Tribulova (2006). Remodeling of connexin 43 in the diabetic rat heart. Molecular and cellular biochemistry, 290, 69-78.

Lisičar, J., T. Scheper, & S. Barbe (2017). Turning industrial baker's yeast manufacture into a powerful zero discharge multipurpose bioprocess. Industrial biotechnology, 13(4), 184-191.

Lu, Y., & L.Y. Foo (2000). Antioxidant and Radical Scavenging Activities of Polyphenols from Apple Pomace. Food Chem. 68, 81–85.

Lyu, F., S.F. Luiz, D.R.P. Azeredo, A.G. Cruz, S. Ajlouni, & C.S. Ranadheera (2020). Apple pomace as a functional and healthy ingredient in food products: A

review. Processes, 8(3), 319.

Martínez-Ladrón de Guevara, E., N. Pérez-Hernández, M.A. Villalobos-López, D.G. Pérez-Ishiwara, J.S. Salas-Benito, A. Martínez, & V. Hernández-García (2016). The actions of lyophilized apple peel on the electrical activity and organization of the ventricular syncytium of the hearts of diabetic rats. Journal of Diabetes Research, 2016.

Nadulski, R., Z. Kobus, T. Guz, K. Strzałkowska, & D. Kosik (2014). The usefulness of the selected apple cultivars for pressing in farm conditions. Agric. Eng, 1, 147-154.

Okokon, E.J., & E.O. Okokon (2019). Proximate analysis and sensory evaluation of freshly produced apple fruit juice stored at different temperatures and treated with natural and artificial preservatives. Global journal of pure and applied sciences, 25(1), 31-37.

Okruhlicova, L., N. Tribulova, M. Mišejkova, M. Kučka, R. Štetka, J. Slezak, & M. Manoach (2002). Gap junction remodeling is involved in the susceptibility of diabetic rats to hypokalemia-induced ventricular fibrillation. Acta histochemica, 104(4), 387-391.

Schieber, A., P. Hilt, J. Conrad, U. Beifuss, & R. Carle (2002). Elution Order of Quercetin Glycosides from Apple Pomace Extracts on a New HPLC Stationary Phase with Hydrophilic End Capping. J. Sep. Sci. 2002, 25,361–364.

Sharma, S., S. Kori, & A. Parmar (2015). Surfactant-mediated extraction of total phenolic contents (TPC) and antioxidants from fruit juices. Food Chemistry, 185, 284-288.

Shashi, B., K. Kalpana, S. Madhu, S. Bikram, & P.S. Ahuja (2008). Processing of Apple Pomace for Bioactive Molecules. Crit. Rev. Biotechnol. 28, 285–296.

Venkatachalam, K., C. Techakanon, & S. Thitithanakul (2018). Impact of the ripening stage of wax apples on chemical profiles of juice and cider. ACS omega, 3(6), 6710-6718.

Will, F., M. Olk, I. Hopf, &H. Dietrich (2006). Characterization of Polyphenol Extracts from Apple Juice. Dtsch. Lebensm.-Rundsch. 102, 297–302.