A Short Review on the Potential of Fruits for the Production of Vinegar with Functional Properties

Hui Yin Fan#, Lee Jau Shya, Mansoor Abdul Hamid, Hasmadi Mamat, Jahurul Haque Akanda, Siti Faridah Mohd. Amin

Faculty of Food Science and Nutrition, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, MALAYSIA.
#Corresponding author. E-Mail: chloefan@ums.edu.my; Tel: +6088-320000; Fax: +6088-320259.

ABSTRACT Vinegar is known for its functional properties due to its health-conferring benefits. Vinegar is a natural food product that is produced from carbohydrate sources via alcoholic and acetic fermentation. Fruits are of great interest to be used in the making of vinegar due to their high contents of carbohydrates and health-associated compounds. This paper reviews the production of fruit vinegar as potential functional foods. Recent studies found that the fermentation of various fruits produced vinegar with reduced sugar content and increased acidity containing acetic acid predominantly. Results also revealed the enhanced antioxidant capacities and antimicrobial properties of some fruit vinegar. Hence, the use of fruits offers potential in the production of vinegar with functional properties.

KEYWORDS: Fruit vinegar, alcoholic fermentation, acetic fermentation, functional properties.
Received 30 November 2020 **Revised** 10 December 2020 **Accepted** 10 December 2020 **Online** 2 November 2021

Review Article

INTRODUCTION

Fruits are rich in phytochemicals that carry various health benefits to the body system, ascribed to their ability in the prevention of radical oxygen species-mediated damage that led to oxidation-linked chronic or degenerative illnesses (Silva *et al.*, 2007). However, most fruits are known as perishable and highly susceptible to spoilage, leading to unwanted post-harvest losses. Nevertheless, other major shortcomings of fruits are due to their agricultural surpluses and substandard, which greatly contribute to food waste and economic problems (Solieri & Giudici, 2009). Many valuable bioactive compounds can be derived from these underutilized fruits. Bioconversion of underutilized fruits into vinegar as potential functional foods is therefore not only serves as a delivery system for these beneficial compounds but also adds value to these fruit wastes (Ghosh *et al.*, 2016). Furthermore, the fermentation of fruits into this valuable vinegar product also promotes locally made products while providing more job opportunities.

Vinegar is often used as a food condiment in the preparation of salad dressings, mustard and mayonnaises (Budak *et al*., 2014). Moreover, vinegar is acknowledged as a functional food which acts as food preservative, medicines, and antioxidants or antimicrobial agents (Budak *et al*., 2014; Shizuma *et al*., 2011; Soltan & Shehata, 2012). Fruits are often used as an ideal carbohydrate source to produce vinegar. The functional properties of fruit vinegar are believed to be derived from the bioactive compounds of the raw materials. Fermentation of fruits into vinegar not only produces acetic acid but also increased other beneficial compounds such as organic acids, volatile compounds, and phenolic compounds (Solieri & Giudici, 2009). In recent years, fruit vinegar has been consumed by health-conscious consumers for their health benefits and medical remedy. Increasing demand for fruit vinegar production is observed lately with the increasing awareness of physiological and biochemical properties gained from the regular consumption of fruit vinegar (Mazza & Murooka, 2009).

PRODUCTION OF FRUIT VINEGAR

Fruits contain fermentable carbohydrates for the making of vinegar. A variety of fruits have been used to produce vinegar, including apples, dates, pears, grapes, berries, melons, coconut (Raichurkar & Dadagkhair, 2017). Among them, vinegar produced from musts of grapes, the balsamic vinegar, contributes to the largest market share, followed by the cider vinegar made with apples (Adebayo-Oyetoro *et al*., 2017). Different fruits produce vinegar with their unique sensory attributes, owing to the substances that originated the raw materials and the formation of compounds from the fermentation processes such as volatile compounds and organic acids (Guerrero *et al*., 2010; Ubeda *et al*., 2012). Vinegar is a sour solution containing not less than 4 g of acetic acid in 100 cubic centimeters of water according to FDA (Food and Drug Administration, USA). Some common parameters of the fruit vinegar measured in recent studies are shown in Table 1.

Table 1. Sugar content, pH value, acetic acid content, and sensory evaluation (9-point hedonic scale) of some fruit vinegar

Fruit Vinegar	Sugar Content (%)[1] / Brix (°Brix)[2]	pH	Acetic Acid (%)	Sensory Evaluation (flavor and taste)	References
Custard apple vinegar	2[2]	2.8	5.39	8.2 – 8.4 (like extremely)	Raichurkar & Dadagkhair, 2017
Date vinegar (Fardh and Honey dates)	7.80 – 14.36[2]	2.83 - 2.77	1.19 -1.89	n/a	Hafzan *et al.*, 2017
Date vinegar (Khistawi)	0.66[1]	3.07	6.84	n/a	Matloob & Balakit, 2016
Grape vinegar	0.4[1]	4.1	6.2	n/a	Kumar *et al.*, 2017
Guava vinegar	0.7[1]	4.4	6.1	n/a	Kumar *et al.*, 2017
Mango vinegar	1.08 – 12.14[2]	4.02 – 4.25	2.5	n/a	Adebayo-Oyetoro *et al.*, 2017
Marula waste vinegar		3.36 – 3.84	4.06 – 5.76	6.0 – 7.0	Molelekoa *et al.*, 2018
Pineapple fruit vinegar	n/a	n/a	6 - 8	n/a	Mohamad *et al.*, 2015
Pineapple waste vinegar	2.2[1]	3.00	5.00	n/a	Roda *et al.*, 2017

n/a: not available

Vinegar is produced via two-stages bioconversion of carbohydrate source. Alcoholic fermentation involves the conversion of natural sugars into alcohol by yeasts under controlled conditions. Subsequently, the alcohol is oxidized into acetic acid by *Acetobacter* bacteria in acetic fermentation (Guerrero *et al*., 2010). Vinegar production is an inexpensive food fermentation process that can be produced at minimal costs using underutilized fruits and fruit waste (Solieri & Giudici, 2009). Various fermentation methods have been reported, with surface and submerged culture fermentations being the two primarily used methods to produce commercial vinegar (Budak *et al*., 2014). The surface cultured method provides oxygen at the surface that allows the culture of acetic acid bacteria to grow. This method is preferable due to its non-destructive nature and it has been successfully applied in the studies of producing vinegar from Khistawi dates (Matloob & Balakita, 2016) and marula waste (Molelekoa *et al*., 2018). Meanwhile, the submerged culture method accelerates the vinegar production by supplying oxygen in the fermentation (Garcia-Parilla *et al*., 1997). Molelekoa *et al.* (2018) found that the submerged culture fermentation was less effective in preserving the bioactive compounds in marula waste vinegar as compared to the surface culture method.

On the other hand, the production of commercial vinegar can be classified into slow or fast fermentation processes. The slow fermentation process involves the accumulation of the acetic acid bacteria that are present in the environment. This method requires a long period of fermentation time over months or years. The fast fermentation process can be completed within hours to days by adding 'mother of vinegar' that contains acetic acid bacteria (Fadzillah *et al*., 2017). The fermentation processes are completed by achieving the acetic acid content that is required for the vinegar. Subsequently, vinegar is usually subjected to further filtration, clarification, distillation, and pasteurization prior to the bottling step (Adebayo-Oyetoro *et al*., 2017).

ANTIOXIDANT AND ANTIMICROBIAL PROPERTIES OF FRUIT VINEGAR

Many studies revealed the regular consumption of fruit vinegar had significantly alleviated certain diseases including hypercholesterolemia, hyperglycemia, hypertension and cancer (Mohamad *et al*., 2015; Samad *et al*., 2016). Vinegar is known to exhibit antioxidant capacity ascribed to the various phytochemicals from the raw materials. These phytochemicals provide protection to the body system from cardiovascular diseases, cancer and other conditions by preventing oxidation of proteins and lipids and other molecules. Different phytochemicals are found in fruits, and the bioconversion of fruit into vinegar produces or increases further the phytochemicals, leading to different antioxidants with enhanced capacities (Budak *et al*., 2014). Apple cider and balsamic vinegar are known as the most prominent ones for their antioxidant capacities (Molelekoa *et al*., 2018). Table 2 shows different total phenolic contents and antioxidant capacities measured for some fruit vinegar in recent studies.

Table 2. Total phenolic content and antioxidant capacities of fruit vinegar.

Fruit Vinegar	Total Phenolic Content (mg GAE/L)	DPPH (%)	FRAP (μg TE/mL)	References
Apple vinegar	459 ± 58	1087 ± 149	323 ± 31	Bakir *et al*., 2016
Date vinegar (Fardh and Honey dates)	571 ± 0.17 – 641 ± 0.03	n/a	n/a	Hafzan *et al*., 2017
Date vinegar (Khistawi)	1453.4 ± 220	n/a	n/a	Matloob & Balakit, 2016
Grape vinegar	842 ± 171	1612 ± 244	568 ± 76	Bakir *et al*., 2016
Grape vinegar	n/a	83.4	n/a	Kumar *et al*., 2017
Guava vinegar	n/a	88.9	n/a	Kumar *et al*., 2017
Mango vinegar	0.513	n/a	n/a	Adebayo-Oyetoro *et al*., 2017
Marula waste vinegar	0.289 ± 0.023 - 0.356 ± 0.032	n/a	n/a	Molelekoa *et al*., 2018
Pineapple fruit vinegar	169.67 ± 0.05	69.28 ± 0.18	357.72 ± 0.07	Mohamad *et al*., 2015

n/a: not available; DPPH is 2,2-diphenyl-1-picrylhydrazyl; FRAP is ferric reducing antioxidant power.

Vinegar is also known for its ability to retard microbial growth. The antimicrobial activity of vinegar is due to its low pH value, ascribed to the predominant acetic acids as well as other organic acids that formed over fermentations, such as lactic acid, propionic acid and succinic acids (Molelekoa *et al*., 2018). Among all these acids, the foodborne pathogenic *Escherichia coli* O157:H7 is effectively eliminated by acetic acids as compared to other organic acids (Budak *et al*., 2014). Apple cider vinegar at 4% concentration exhibited antifungal properties against *Candida spp.* (Mota *et. al*., 2015). Several factors affect the antimicrobial activity of vinegar, such as temperature, pH, concentration of acetic acids and ionic strength (Budak *et al*., 2014).

CONCLUSION

A variety of fruits are potential to be used in making vinegar with functional properties, owing to their health benefiting compounds that exhibit potent bioactive effects. Moreover, fruits are ventured into producing vinegar with commercial value as an alternative to reduce the postharvest losses, while value-adding to the underutilized fruits.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support from University Malaysia Sabah, under the Skim Geran Inovasi (SGI0109).

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