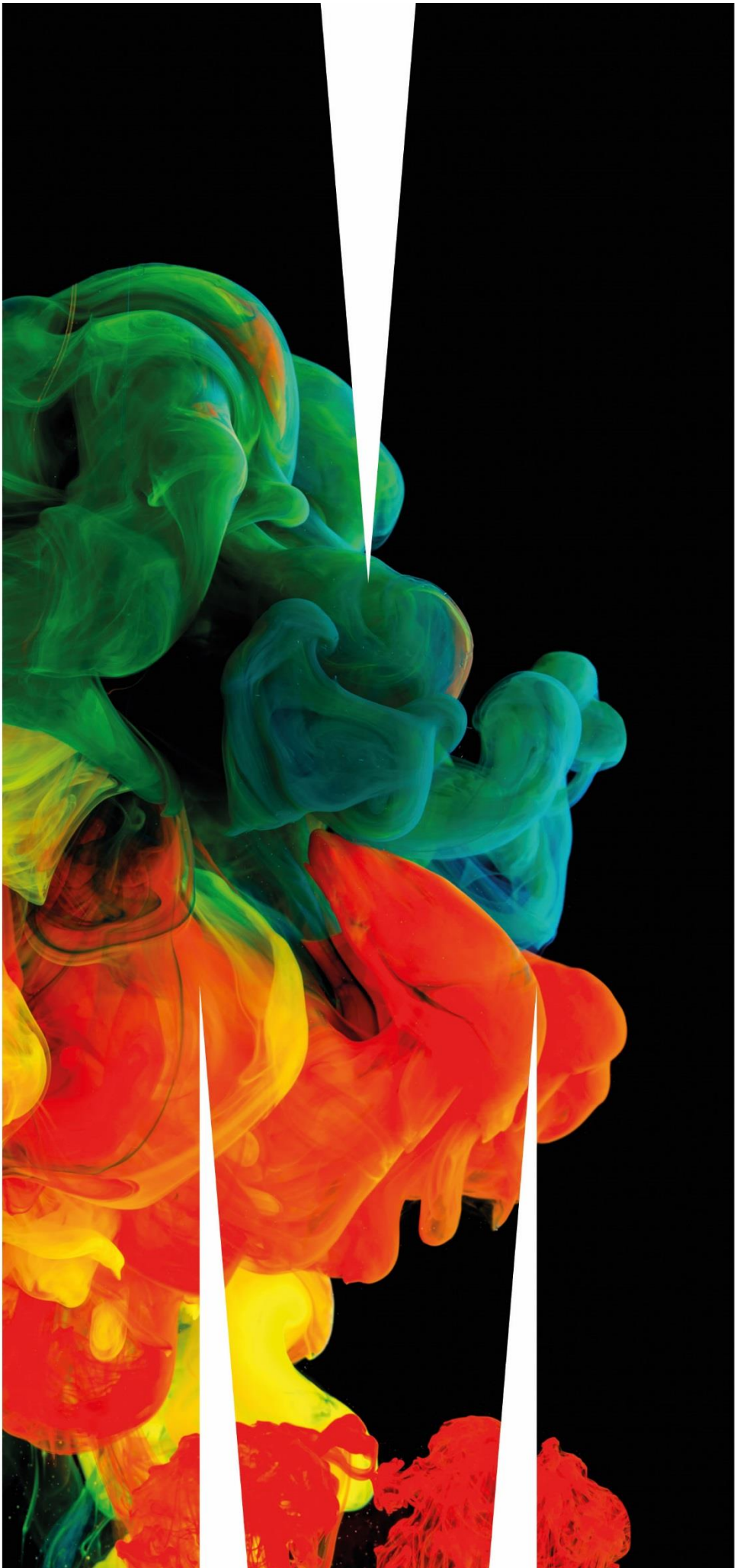
MONASH University



Literature Review – Valorisation options for stone fruit waste

For

SUSTAINABILITY VICTORIA AND CUTRI FRUIT

Prepared by Dr Karen Little, Professor Tony Patti and Professor Victoria Haritos

Monash University, Clayton, VIC 3800

Email: tony.patti@monash.edu

victoria.haritos@monash.edu

karen.little@monash.edu

Abstract

The significant loss of stone fruit on-farm and in waste streams from fruit processing represents largely untapped resources of nutrients that could be utilised in value-added products. This literature review explores the composition of discarded fruit and fruit components (skin, kernels, pulp) and focuses on the use of recoverable bioactive compounds such as antioxidants, oil and dietary fibre in food and beverage production and higher end markets such as cosmetics and nutraceuticals. For each suggested product or application, a broad assessment of the processing input and the proportion of fruit utilised has been made based on the maturity of the technology, the number of steps involved and the consistency and purity required. To use substantial amounts, the stone fruit may need to undergo a number of processes. In addition to the processing rankings given, all aspects of transport costs need to be considered including maintaining the stone fruit waste in a form that is suitable for valorisation.

1. Introduction

Around three-quarters of the peaches and nectarines grown in Australia are grown in Victoria, with Renmark, Swan Hill and the Goulburn Valley (Shepparton and Cobram) producing more than 50% of Australia's summer stone fruit production. Up to 30% of all crops are discarded or lost on-farm in sorting processes, amounting to hundreds of thousands of tonnes annually of discarded fruit across the sector. The causes of loss include immature fruit, extreme weather events, pest damage and low consumer acceptance of size or shape due to the environmental conditions during the growing period. Waste streams are also produced during stone fruit processing including waste in the form of pomace from juicing and stones and skins from juicing, pureeing and canning.

The disposal of waste fruit as animal feed represents limited or no value to the growers and is a loss of important nutrients including oils, antioxidants, vitamins and pigments that can provide health benefits and natural colourants. The consumer demand for products in the beauty and personal care, nutraceutical and food and beverage sectors which are fortified with naturally sourced additives that have health benefits is growing. This is driven by the rising costs of health care, social media and a heightened awareness of health due to COVID-19.

This literature review will address the challenge of valorising the large quantity of stone fruit waste associated with the growing and processing of stone fruits in northern Victoria. The objectives are to explore value-added products of discarded fruit and fruit components (skin, kernels, pulp) with a focus on higher value products for use in either food production and in higher end markets such as cosmetics and nutraceuticals.

2. Method

Searches of databases including Scopus and SciFinder^{n} for scientific research papers were conducted. A search of patents was conducted using Lens (www.lens.org). Due to the large number of patents, only those granted within the past ten years were considered. A selection of appropriate patents is summarised in Section 7. The keywords and terms used included *stone fruit valorisation* and combinations of *peach*, *apricot*, *nectarine*, *plum*, *pomace, waste* and *valorisation*. As appropriate papers were identified, further search terms used were specific to industry sectors and applications. The papers selected were restricted to those published in the English language. No geographical restrictions were applied, and the search was not limited to papers published within a specific time frame. Some industry sectors and concepts were explored further using publicly accessible websites.

To identify appropriate clinical trials, searches were conducted of the database ClinicalTrials.gov (U.S. National Library of Medicine). The search terms used were *peach*, *apricot*, *nectarine* and *plum*. Only clinical trials with results reported in published scientific research papers have been included.

The content of the literature review is organised into three main sections. Section 3 describes the composition of each part of the fruit, including the pomace remaining after juicing. Section 4 describes potential value-added products for the waste and is separated into subsections which explore cosmetic, nutraceutical and food applications. Section 5 is a summary of the processing requirements for the extraction of compounds of value. Section 6 is a summary table of the value-added products and assessment of the volume of fruit that would be utilised and the processing required. Section 7 is a summary of selected patents that describe the use of stone fruit other than in the form of juice.

3. Composition of stone, kernel, flesh and skin

Before considering the options for stone fruit waste use, it is important to assess the composition of each part of the fruit. The types and content of compounds present in the stone, kernel, mature and immature flesh and skin provided here are obtained from scientific literature. The composition is

highly dependent on the variety and growing conditions and so depending on the valorisation option of interest, for each grower, season to season, these values should be verified in a laboratory. The composition of pomace, the solid remains following pressing of the fruit, has also been included as it is a common waste stream from juicing.

3.1 Stone composition

The stone, otherwise known as the pit or endocarp (Figure 1), ranges between 3-8% of the total fresh fruit mass, depending on the variety and growing conditions (Kamel and Kakuda, 1992). The stone is composed mostly of lignin (36-37%), cellulose (20-22%) and hemicellulose (24-27%) (Behaghel de Bueren et al., 2020, Núñez-Decap et al., 2021), which are associated with cell walls and provide structural stability. Lignin is highly resistant to chemical and biological degradation whereas cellulose and hemicellulose are somewhat easier to degrade. These properties mean that the stone is relatively stable and inert when incorporated into moisture-containing products.

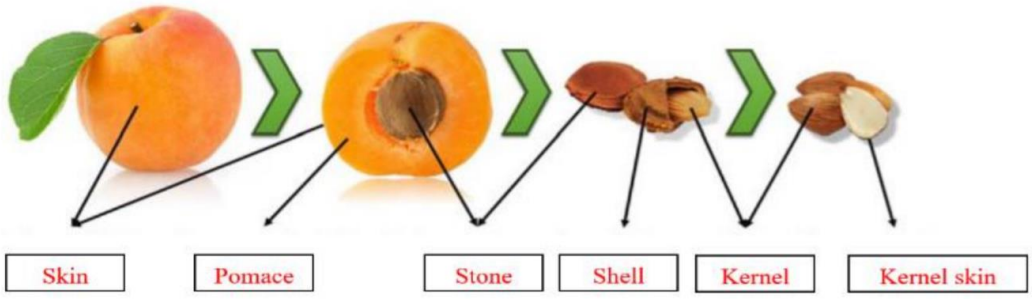


Figure 1: Apricot by products (Kasapoglu et al., 2020).

3.2 Kernel composition

The kernel mass ranges between 7-32% of the stone mass and the kernel moisture ranges between 39-72% depending on the variety and growing conditions (El-Aal et al., 1986, Kamel and Kakuda, 1992). The kernel is composed of between 40-50% fatty acids (oils), 4-8% crude fibre and 15-45% crude protein (Ozcan, 2010, Abd El-Aal et al., 1986).

The dominant fatty acids in peach and apricot kernels are oleic acid (50-70%) and linoleic acid (20 – 30%) which are unsaturated, with small amounts of saturated fatty acids such as palmitic acid (4-8%) and stearic acid (0.5 – 1.5%) (Kamel and Kakuda, 1992, Fratianni et al., 2018, Ozcan, 2010). Oleic acid is a monounsaturated omega-9 fatty acid and consumption can reduce the risk of cardiovascular disease, blood pressure and protect against age-related cognitive decline (Sakurai et al., 2021, Terés et al., 2008). Linoleic acid is a polyunsaturated omega-6 fatty acid and is important for the development and maintenance of the nervous system and the reduced risk of cardiovascular disease (Froyen and Burns-Whitmore, 2020).

Stone fruit kernels also contain compounds which have antioxidant capability including β-carotene which when ingested is converted into vitamin A and tocopherols which are forms of vitamin E (Fratianni et al., 2018, Wu et al., 2011). The mineral content of the kernel is generally high in calcium, potassium, magnesium and phosphorus (Ozcan, 2010).

Stone fruit kernels are rich in protein, ranging between 14-45% depending on the variety (Alpaslan and Hayta, 2006). The protein is easily digestible and contains the essential amino acids threonine, valine, leucine, isoleucine and lysine which cannot be produced in the human body and need to be consumed as part of a food source (Rahma and El-Aal, 1988).

Apricot and peach kernels contain the compound amygdalin which when ingested, produces cyanide in the gut, leading to nausea, fever, headaches, lethargy, joint and muscle pain and in some cases death. Generally apricot kernels have double the content compared to peach kernels, with 14 mg/g and 7 mg/g respectively (Bolarinwa et al., 2014). The extraction of amygdalin is fairly straightforward, with the kernel milled and treated with water or a solvent such as ethanol or methanol. Extraction should be considered when kernels are used for a product that is intended for consumption. There are reports including those published in scientific journals that amygdalin supplied as Laetrile or vitamin B17 can be used as a cancer treatment (Chang et al., 2006, Chen et al., 2020). These reports are based on findings from the application of amygdalin to cells in laboratory conditions, there have been no reported human trials conducted. The Therapeutic Goods Administration of Australia (TGA) have deemed amygdalin to be a substance which is dangerous to health, with no clear evidence of therapeutic benefit and the sale of raw apricot kernels for direct consumption has been prohibited by the Food Standards Code (Food Standards Australia New Zealand, 2017, Therapeutic Goods Administration, 2021, Food Standards Australia New Zealand, 2015). Therefore, cancer treatment as part of the nutraceutical/supplement industry sector has not been explored in this review.

3.3 Mature and immature flesh and skin composition

Stone fruit flesh and skin contains a range of compounds referred to as phenolic compounds. In the context of their function within the fruit, they contribute to sensory attributes such as aroma, taste, and colour and provide protection from ultra violet (UV) radiation (Stevanato et al., 2014). These compounds include hydroxybenzoic and hydroxycinnamic acids, catechin, epicatechin, quercetin, chlorogenic acid, neochlorogenic acid, ferulic acid and coumaric acid (Redondo et al., 2021). When consumed, these compounds can have health benefits largely due to their antioxidant capability. This means that they can scavenge and neutralise free radicals that are produced in the body as part of normal metabolic processes. Conditions caused by free radicals can include deterioration of vision, joint inflammation, deterioration of neurological function, increased risk of coronary disease and certain cancers (Southorn and Powis, 1988). For simplicity of terminology, henceforth the term ‘antioxidant’ will be used when discussing all phenolic compounds contained in stone fruit flesh and skin.

Generally, the antioxidant content in the skin and flesh of thinned, immature apricots, peaches, nectarines and plums is greater than that in commercially mature fruit (Redondo et al., 2021). For example, the concentration of antioxidants in the immature flesh of plums and peaches can decrease by 70-80% in the mature fruit (Redondo et al., 2017). Studies indicate that there is variation not only between the immature and mature fruit but also variation between the different fruit components. Generally there is a much higher concentration of antioxidants in the skin compared to the flesh, generally two to four times higher (Serra et al., 2020). Plums have a higher antioxidant content than peaches, nectarines and apricots (Gil et al., 2002). For peaches and nectarines, generally white and yellow flesh are similar in terms of antioxidant content however it depends on the variety (Serra et al., 2020, Gil et al., 2002).

During ripening, the content of the antioxidant compounds referred to as anthocyanins increases. These compounds are responsible for the rich colour of the mature skin and flesh. Some varieties of plum are particularly high in anthocyanins, with up to 800 mg/100 g, mainly concentrated in the skin (Francis and Markakis, 1989).

Stone fruit are a good source of minerals particularly potassium but also zinc, calcium, iron, magnesium, manganese and phosphorus (Heidari, 2016, Bennett et al., 2010, Fratianni et al., 2018).

Adequate potassium intake generally helps to maintain a proper fluid balance, aids muscle function, maintain a normal blood pressure and contributes to regulate heartbeat (D'Elia et al., 2011).

Stone fruit flesh is a good source of dietary fibre, which is particularly concentrated in the pomace remaining from juice production. Fibre is composed of a mixture of plant carbohydrate polymers that make up the cell wall and is classified as soluble or insoluble based on its solubility in water. Pectin, inulin and other non-starch polysaccharides are soluble whereas cellulose, hemicellulose and lignin are insoluble (Maphosa and Jideani, 2016, Gidley and Yakubov, 2019, Meena et al., 2021). Each type has different physiological effects, with insoluble related to water absorption and bowel regulation, whereas soluble is associated with the reduction of blood cholesterol and the control of glucose absorption. As more is becoming known about the importance of the gut microbiome on all aspects of health, some types of soluble fibre are now known to provide a substrate for microbes to produce short chain fatty acids which are associated with a reduction in colon cancer, type II diabetes, inflammatory and cardiovascular diseases (Prasad and Bondy, 2019).

Typically, peach pomace can have a total dietary fibre content of 36-58% (dry matter basis), comprising of 26-40% insoluble fibre and 10 -18% soluble fibre (Grigelmo-Miguel and Martín-Belloso, 1999a, Pagán et al., 2001). Plum pomace may have a total dietary fibre content of 50% (dry matter basis) comprising of 30-40% insoluble fibre and 8-10% soluble fibre (Milala et al., 2013). One type of soluble fibre found in stone fruit flesh is pectin, which is a polysaccharide made up of a galacturonic polymer backbone. Various levels of other simple sugars form short segment side chains, including D-galactose, L-rhamnose, L-arabinose and D-xylose (Blanco-Pérez et al., 2021). Pectin is used for its jellifying, thickening and stabilising properties largely in the food industry but can also be used in the pharmaceutical, dental and cosmetic industries.

4. Value-added products for stone fruit waste

With growing consumer knowledge about wellness, wellbeing, the nutritional value of fortified and natural foods along with environmental sustainability, it’s an ideal time to explore value-added products from stone fruit waste. A range of options are presented based on the industry sector, with a focus on the higher value products.

4.1 Beauty and personal care sector

The Australian beauty and personal care products market was valued at AUD $5.2 billion in 2020 and is forecast to continue growing (Mordor Intelligence, 2021a). Producers of these products target millennials who follow trends closely and are highly influenced by social media. Purchases are made based on product claims which may or may not have a well-tested, scientific basis. Skincare products represent a significant proportion of the market and the current trends are for vegan and organic products that are ethical and sustainable, which increases the price point of the product. The incorporation of fruit extracts is highly desirable for aroma and antioxidant value, although they may represent only a small proportion of the final product. Personalised skin care systems are also popular and reflect consumers wanting to be knowledgeable about ingredients and make decisions about the formulation of the products that they use. As an example, in previous times a moisturiser such as Olay (also known as Oil of Olay) was a common household name and was offered as a very limited product range. Skincare is now far more complex with a wide range of product options including antioxidant and vitamin preparations, offering a skincare regime which is adaptable to skin condition at the time. Due to these trends, there are opportunities for utilisation of all parts of the fruit within the beauty and personal care sector.

Exfoliant products

Natural exfoliants have been used extensively in rinse-off personal care products such as body, face and foot scrubs and also in industrial hand cleaners. With the development of microbeads and their incorporation into commercial products in the 1990's, natural exfoliants were replaced. Now, with the growing understanding of the persistence of microbeads in the environment and the damaging effects on marine life, the environment and human health, there is a need to once again return to exfoliants from natural sources (Hunt et al., 2021, Cheung and Fok, 2016). Australia's position on the replacement of microbeads has been through voluntary industry phase out in imported and locally manufactured products (Accord, 2019).

For incorporation into rinse-off exfoliant products, processing of the stones would be relatively straightforward. The stone would need to be cleaned and dried and the kernel removed for other purposes. The stones could then be milled to specific mesh sizes to suit the application. While there is no evidence of an Australian provider of peach or apricot stone powder, there are international companies who prepare a range of naturally derived powders for cosmetics, industrial and food applications. Incorporation of milled stone into products results in natural colouring of the product which is also highly desirable due to the negative impact of artificial colourants on health.

Skin and hair care

Opportunities for kernels

The most widely known use for the kernel of stone fruit is for the oil which is commonly used in soap, shampoo, skincare serum and moisturiser. The high linoleic and oleic fatty acid content makes it ideal for creating a barrier to help retain moisture in dry skin and hair. From apricots, plums or peaches, it's a light coloured and easily absorbed oil that doesn't leave a greasy residue. The kernel oil is odourless and so can be used as a carrier of other fragrances such as essential oils for aromatherapy and massage (Michalak, 2018). Nectarine kernel oil is not as often seen in beauty products perhaps due to a slightly lower yield compared to that from peach and apricot kernels however the high antioxidant content makes this an underutilised resource (Sodeifian and Sajadian, 2021, Chamli et al., 2017).

Both peach and apricot kernel oil contain high levels of vitamin E and are commonly included along with retinol and vitamin C in anti-aging topical creams and serums (Aksoz et al., 2020). These products are marketed with claims such as 'skin tightening', 'fighting free radical damage' and 'reversing the signs of aging, lines, elasticity and uneven skin tone'. There has been some scientific basis that supports the benefits of vitamin E in the reduction of wrinkles and dark circles of the lower eyelids (Mitsuishi et al., 2004). Apricot kernel oil has been shown to have anti-inflammatory and antimicrobial properties and has been used in traditional forms of medicine as a remedy for skin infections (Lal and Singh, 2008). It would be a beneficial inclusion in products for acne treatment and rosacea and has been shown to be a promising candidate for the treatment of psoriasis (Lee et al., 2014, Ayres and Mihan, 1981, Li et al., 2016).

Opportunities for stone fruit flesh and skin

Due to the popularity of skincare products which contain fruit extracts, antioxidants extracted from thinned and/or mature peach, plum, nectarine and apricot could be formulated into products such as face cleansers, toners, moisturisers, skin mists, eye creams, serums, specialised serum supplements, body butters and body wash. Face sheet masks for skin moisturising and repair are very popular and consist of a base made of natural or synthetic fibre impregnated with the moisturising product which usually has a fruit extract component. The cost of sheet masks ranges from $4 to $10 per mask and the frequency of use depends on the individual but may be up to two times per week. They are single use and so the selection of base material is important, with preference for a biodegradable material.

Ceramides are a type of lipid and are naturally found in skin cells. Their function is to protect skin from environmental damage, most notably dehydration. As skin matures, the natural ceramide content decreases, resulting in a change of skin texture which is associated with aging. A type of ceramide can be extracted from peach flesh and skin and when taken as a supplement or applied topically has demonstrated anti-aging properties by improving skin water retention and texture (Koikeda et al., 2017, Park et al., 2012).

4.2 Nutraceuticals

The term 'nutraceutical' is used to describe any food or a component of food that can provide medical or health benefits, including the prevention and/or treatment of a disease, delaying the aging process and/or increasing life expectancy. This includes vitamins, minerals, supplements, enzymes, fatty acids, proteins, antioxidants, pre and probiotics and fortified foods which are enriched with nutrients. In this section, opportunities for stone fruit waste incorporation into encapsulated supplements will be explored, with fortified foods and beverages addressed in Section 4.3.

The Australian nutraceuticals market is expanding due to a growing preference for personalised nutrition and increasing demand by elderly consumers in response to rising health care costs (Mordor Intelligence, 2021b). The impact of COVID-19 has also increased demand, as consumers have become more aware of potential immunity benefits (Pastor et al., 2021). A recent report suggested significant financial opportunities for Victoria by the extraction of compounds with nutritional value from food waste for applications in nutraceuticals (Commonwealth Scientific and Industrial Research Organisation, 2020). In Australia, nutraceuticals are regulated under the Therapeutic Goods Act of 1989 and there are specific requirements associated with making health claims.

The use of antioxidants derived from natural sources to treat disease is appealing. There have been a number of studies conducted in cells and animal models which suggest that the antioxidants in stone fruit flesh and skin could have preventative effects for cancer, hypertension and some neurological diseases. Extracts of antioxidants from peach and plum inhibited the growth and metastasis of breast cancer cells (Vizzotto et al., 2014, Noratto et al., 2014) with a similar finding from a concentrated apricot extract (Nakagawa et al., 2007). Apricot extract inhibited the growth of cancerous liver cells (Okada et al., 2007) and plum and peach extracts inhibited the growth of colon cancer cells (Lea et al., 2008). When orally administered, proteins extracted from peach kernels have demonstrated a reduction in blood pressure in rats (Vásquez-Villanueva et al., 2015, Vásquez-Villanueva et al., 2019). In laboratory conditions, an extract of antioxidants from apricots prevented accumulation of a specific protein responsible for impairing cognitive functions such as memory and language which are associated with Alzheimer's disease (Katayama et al., 2011). While these results are promising, there is a significant difference between the findings of trials conducted in cell lines and animal models to those in human clinical trials. To date, there is no evidence of the assessment of these preliminary results in clinical trials.

Encapsulated, extracted antioxidant compounds or a powdered form of the stone fruit flesh could be produced as a dietary supplement, there are significant opportunities here for the thinned, immature fruit, which has a higher concentration of antioxidants compared to the mature fruit. In an encapsulated form, flavour is not important. Commonly, nutraceutical products are blends with other natural materials. A current example available on the Australian market is peach powder blended with marine collagen for the maintenance of healthy hair, nail and skin.

Scientific evidence and clinical trials have worked well to promote Queen garnet plums, marketed as the 'Queen of Antioxidants' (Bhaswant et al., 2019, Netzel et al., 2012, Santhakumar et al., 2015). As well as freeze dried powder prepared from the flesh and skin, the nutraceutical range extends to pre

and probiotic supplements based on the plum's soluble dietary fibre content and with the addition of bacteria for good gut health (Nutrafruit, 2021).

4.3 Food and beverage sector

Foods and beverages supplemented with nutrients that provide additional health benefits are very popular. The antioxidant and dietary fibre content of stone fruit flesh and skin makes it ideal for the addition or partial replacement of ingredients to produce a more nutritious food product. The unsaturated oil from the kernel can be used to replaced saturated oil in food products, thereby maintaining the texture and flavour but reducing the health risks. The addition of flour produced from defatted kernels can be used to increase the protein content of foods.

Oil and shortening replacements

Peach, plum and apricot kernel oil can be used as edible oils and as substitutes for oils with high saturated fat content in products such as salad dressing, dips, and sauces. They are stable at room temperature and also at moderate and high temperatures, making them suitable for cooking (Durmaz et al., 2010). The oils can be extracted from the kernel by cold pressing which retains their nutritional value. The amygdalin content of the oil is low, generally one tenth of that in the kernel itself (Pavlović et al., 2018). Stone fruit kernel oils would be considered as a niche market. There appears to be very limited production in Australia and are at a higher price point compared to Australian produced olive oil which is approximately one third of the cost.

In bakery goods such as sweet and savoury biscuits, muffins and cake, oil and shortening are the principal ingredients that influence the texture and flavour. Stone fruit pomace has been demonstrated to replace up to 4% of sunflower oil in muffins which were determined to have acceptable taste and texture by a sensory panel (Grigelmo-Miguel et al., 2001). The partial replacement of oil results in a product that is lower in calories and higher in moisture and fibre. Ground whole apricot kernels or the extracted kernel oil can be used to partially replace shortening in sweet and savoury biscuits and cake. The resulting products are higher in dietary fibre and protein and contain less saturated fat (Seker et al., 2010, Özboy-Özbaş et al., 2010, Abd El-Aal et al., 1986).

Protein enriched foods

Foods high in protein were once marketed to athletes and body builders but have now become popular with mainstream consumers due to the popularity and reported benefits such as weight loss and craving satiety of high protein diets.

Due to dietary intolerances and health trends, there is growing interest in flour that is not derived from a gluten-containing grain source. Banana flour is an example of an alternative flour which has been growing in popularity largely due to consumer marketing of the resistant starch content and its beneficial effects on digestive health (Rosado et al., 2021). Flour produced from defatted apricot and peach kernels which have been processed for amygdalin removal, is high in protein (approximately 30%) and rich in potassium and magnesium minerals, as well as B group vitamins (Lima et al., 2014).

Kernel flour has been used to enrich wheat-based bread with up to 8% of wheat flour replacement without compromising the physical and textural properties (Dhen et al., 2018). Partial replacement of wheat flour in noodles resulted in a product with increased protein and decreased cooking time (Eyidemir and Hayta, 2009). Pasta with replacement of a portion of semolina has been trialled with some success (El-Demery and Elsanat, 2010). Other opportunities could include breakfast cereal and wheat-based snack bars. Apricot kernel skins are also high in protein (approximately 10%) and have also been added to bread to partially replace wheat flour (Yao et al., 2021). Apricot kernel flour is

commercially available however there doesn't appear to be an Australian manufacturer. There is no evidence of commercial availability of other stone fruit kernel flours.

Fibre enriched foods

The importance of dietary fibre intake for the maintenance of digestive health and to reduce the risk of developing chronic diseases has been well established. More recent studies have suggested that diets that are high in soluble dietary fibre are beneficial for gut health through the microbial production of short chain fatty acids. There is evidence to suggest that these fatty acids regulate a range of metabolic and immune responses and influence brain function, with connection now being made between the impact of inadequate intake of dietary fibre on poor mental health (Rees et al., 2021). It has been reported that less than 20% of Australian adults meet the recommended fibre intake to reduce the risk of chronic disease (Fayet-Moore et al., 2018). These factors have led to an increase in the availability of food products that are enriched with dietary fibre.

Extruded snack foods are generally high in saturated fats and processed sugar and are of low nutritional value. Consumer demand for versions that are lower in calories and provide nutritional benefits provides an opportunity for dried stone fruit pomace to be used to fortify cereal based snacks (Sarkar and Choudhury, 2021). The natural sugar content of the pomace would replace processed sugar and the natural colour of the pomace could reduce the need for artificial colourants. The extrusion of snack foods from waste biomass has been the subject of trials conducted by the CSIRO Food Innovation Centre located in Werribee. Stone fruit purees can be extruded and dried into fruit leather. If composed only of fruit with no added sugar, this is a nutritious, easily portable snack (Akdogan and McHugh, 1999, Roknul Azam et al., 2019).

Stone fruit pomace has a high-water holding capacity and gelling properties due to the presence of pectin, thereby reducing the use of commercial thickeners (Grigelmo-Miguel and Martín-Belloso, 1999b). These properties make stone fruit pomace ideal for adding into jams, sauces, yoghurt and ice-cream (Grigelmo-Miguel and Martin-Belloso, 2000, Grigelmo-Miguel and Martín-Belloso, 1999b, Kasapoglu et al., 2020). Improving the nutritional profile of ice cream with the addition of dietary fibre from fruit has been explored (Soukoulis et al., 2009, Akalın et al., 2018, Mansour et al., 2021, Villalva et al., 2017) and at present there are a limited number of products on the market that are targeted to aged care to ensure adequate nutrition for people who have dysphagia or low appetite in an easy to consume, enjoyable product.

The high-water holding capacity of stone fruit pomace makes it ideal as an ingredient in bakery products to increase and retain the moisture content as well as improving the nutritional value. While incorporation into bread has been problematic for maintaining texture (Quiles et al., 2018), dried stone fruit pomace has been successfully incorporated into biscuits (Singh and Kulshrestha, 2016) and muffins (Grigelmo-Miguel et al., 1999).

Freeze drying fruit is an ideal way to prolong shelf life and produce an intensely flavoured, high nutritional value snack food without added sugar, preservatives or colours. There are Victorian based companies who specialise in freeze drying. The fruit can be packaged as pieces for snacking or powdered. Powdered fruit can be included in a wide range of foods for its nutritional value, natural colour and taste, particularly where the water content of the fresh fruit would create issues such as some baked goods, decorative icing, meringue, buttercream and marshmallow (Özboy-Özbaş et al., 2010).

Beverages

The beverage industry offers opportunities for the use of stone fruit mature flesh as whole or dried pieces, juice or puree. With a focus on health and wellness, consumers prefer authentic, natural flavourings rather than synthetic versions.

The smoothie market in Australia is growing due to a preference for consuming whole fruit including the dietary fibre rather than only the juice. A smoothie is whole fruit blended with milk or yoghurt and can include other additives such as whey protein powder, spices such as ginger and turmeric and seeds such as chia and flaxseeds. Expanding on smoothies purchased from a commercial storefront, there is now a growing industry that provides options for preparing smoothies at home in a convenient way that is appealing to time poor consumers. A number of companies in Victoria home deliver individually packaged ready-to-blend smoothie packs which contain a number of fruit types along with additives such as cacao, nuts, ginger and spirulina. Smoothie bombs are a concentrated version of a smoothie pack and can also home delivered. Good marketing is essential, with each type of smoothie given an appealing name along with health claims based on the ingredients.

Cold water infusions are a popular way to increase water intake and a relatively new to the market, with products available to consumers only approximately four years ago. Dried fruit pieces are enclosed in a mesh bag, similar to a tea bag, and are used to flavour cold water, making it more palatable. Generally, these products contain fruit blends and sometimes spices, with no artificial colours or flavours. Traditional tea can also be flavoured with dried fruit, with peach being a common complementary flavour. Bubble tea, also referred to as boba, originated in Taiwan in the 1980s and has been quickly growing in popularity in Australia over the past few years. As well as a rapidly expanding number of storefronts and franchises, bubble tea kits have recently become available for preparation at home. Bubble tea was initially popular due to the novelty of tapioca pearls sitting at the bottom of a cup of milk tea and was a textural experience to consume. It has maintained its popularity by the expansion of milk-based tea to fruit flavours, including peach. While artificial flavouring is used, there generally is a proportion of natural fruit juice used. The sugar content of bubble tea is very high in both the milk and fruit versions. Stone fruit powder could be a way of providing sweetness and flavour without adding refined sugar.

Fermented drinks such as kombucha and kefir are popular in ready to drink options. Kombucha is a fermented sweetened black or green tea drink whereas kefir is produced from milk fermented with kefir grains. Both contain probiotic bacteria which are beneficial for gut health (Maldonado et al., 2019). The palatability of these drinks is improved greatly with the addition of natural flavouring which presents an opportunity for stone fruit puree. There are a number of commercial brewing operations in Victoria.

There are a number of alcoholic beverage options that can be flavoured with stone fruit including prosecco, cider, seltzer and gin. Boutique wineries and distilleries may provide opportunities for the use of stone fruit flesh as a natural flavouring either as a base ingredient or for flavouring the final product. Alcohol free spirits, cocktails and wine are growing in popularity likely due to a growing focus on wellbeing, a shift in attitudes around alcohol and inclusivity for those who want options other than water and soft drink at social events. Again, the requirement for a natural flavouring would provide opportunities for stone fruit.

4.5 Natural colourants

Natural colourants are added to food, cosmetics and pharmaceuticals to make them visually attractive, to restore the original appearance after processing, for product identification and to assure colour uniformity in products which may be affected by seasonal variation. The demand for natural

colourants from plant sources is increasing due to the increased awareness of the health risks of synthetic colourants which includes allergic reactions, behavioural and neurocognitive effects and possible carcinogenic effects. Asia-Pacific is the fastest growing market, with an increase in the demand for processed food increasing the demand for colourants (Mordor Intelligence, 2021c). Also, there is consumer demand for 'clean label ingredients' which refers to the use of simple ingredients that consumers can easily recognise. While demand is increasing, it is not being met by Australian producers and there is a heavy reliance on imported products. There are challenges in the cost-effective production of natural colourants that give a strong, consistent colour and are stable at a range of temperatures and pH. While they are derived from natural sources, natural colourants are subject to a Food Standards Australia New Zealand (FSANZ) approval process.

Anthocyanins are the compounds that give fruit its natural colour and also have antioxidant capability. Nectarines, peaches and apricots are relatively low in anthocyanin content at 4-6 mg/100g fresh weight however plums have a comparatively high content at 125 mg/100g fresh weight (Wu et al., 2006). Plum peel extracts have shown excellent stability up to pH 5.0, which is the typical upper pH limit for maintaining a rich red/purple colour from a natural source (Hernández-Herrero and Frutos, 2014). Technologies such as spray drying and microencapsulation are making natural colourants easier to use and colour stable. Rather than an extract of the anthocyanins, freeze dried plum powder prepared from the flesh and skin could be used as the colourant.

5. Processing and extraction of compounds of value

Extensive processing of stone fruit waste should be avoided to minimise the environmental impact and cost. Recently, technologies are being developed that are green and sustainable, which includes consideration of processing inputs and outputs including chemicals, solvents and energy (Anastas and Warner, 1998).

To extract the oil from stone fruit kernels, they first need to be separated from the stone and crushed. The most common techniques to extract the oil are by using an organic solvent, supercritical extraction by carbon dioxide or cold pressing. Supercritical extraction and cold pressing would be considered the greener technologies. Solvent extraction is the more mature technology, offering a low cost method of extracting edible oils. The yield and chemical composition of the extracted oil (Table 1) is similar for both methods (Vladic et al., 2020, Pavlović et al., 2018).

Table 1. Fatty acid composition of apricot kernel oils. Taken from Pavlović et al. (2018).
Abbreviations: SC-CO_2 supercritical extraction by carbon dioxide. CP cold pressed.

Fatty acids	SC-CO_2 oil [%]	CP oil [%]
Palmitic acid (%)	5.93 ± 0.91^a	5.79 ± 0.65^a
Palmitoleic acid (%)	0.92 ± 0.00^a	0.93 ± 0.10^a
Stearic acid (%)	1.46 ± 0.35^a	1.24 ± 0.01^a
Oleic acid (%)	57.33 ± 2.80^a	62.73 ± 1.23^b
Linoleic acid (%)	33.81 ± 2.15^a	29.18 ± 1.99^a
Saturated fatty acids (%)	7.57 ± 0.43	6.82 ± 0.35
Unsaturated fatty acids (%)	92.43 ± 0.43	93.18 ± 0.54
Monounsaturated fatty acids (%)	58.45 ± 2.54	63.86 ± 2.13
Polyunsaturated fatty acids (%)	33.98 ± 2.14	29.31 ± 1.63

Data are expressed as mean value of replication (n) $\pm$ SD. The same letter in the same rowof analyzed variable indicates no significant differences (Duncan's test, $p < 0.05$).

Following extraction of oil from the kernel, the protein can then be extracted. This is generally achieved by solubilising the proteins in an alkaline solution and then coagulating by reducing the solution pH (Sharma et al., 2010). Following filtration and drying steps, the protein isolate can then be used to prepare a protein enriched product.

Dietary fibre can be extracted as whole fibre, as soluble or insoluble or as its individual constituents. All methods involve some form of initial fractionation which allows unwanted components to be eliminated. There are a range of extraction methods including dry or wet processing, chemical, gravimetric, enzymatic and microbial. There are numerous variations of each. The extraction method selected is based on the required end product. For example, a chemical method will extract total dietary fibre whereas a wet processing method will extract the soluble fibre (Maphosa and Jideani, 2016).

Traditionally, organic solvents such as ethanol, methanol and acetone have been used to extract antioxidant compounds from fruit (Mokrani and Madani, 2016). Although the process generally provides good yields, it uses large volumes of solvent and long extraction times. The more recent development of ionic liquids and deep eutectic solvents provides green solvent options however the toxicity of these types of solvents has not been fully resolved. More recent technologies including ultrasonic, enzyme, or microwave-assisted and pulsed electric field extraction reduces the time, temperature, solvent and energy requirements through the disruption of the fruit tissue and release of the antioxidants (Kumar et al., 2021, Carpentieri et al., 2021, Redondo et al., 2018).

Freeze-drying is method of preserving food by the removal of moisture and is carried out at low temperature and pressure. This ensures that the aroma and nutritional content of the food is retained. (Harguindeguy and Fissore, 2020). This method could be used to produce powders of the dried flesh and skin for high-value applications such as inclusion in skin care products. The process is highly energy and time intensive and is expensive, with the capital, operational, and maintenance costs of freeze-drying units four to eight times higher than conventional hot air drying units (Waghmare et al., 2021). The use of supplementary technologies such as microwave, ultrasonics and pulsed electric field can assist in reducing the energy inputs and processing time (Waghmare et al., 2021).

6. Summary of value-added products

The aforementioned value-added products have been summarised in Table 2, along with a broad assessment of the processing input required to prepare the fruit waste for use in the product and the proportion of fruit utilised. Low, medium and high ratings of processing input have been allocated based on the maturity of the technology, the number of steps involved and the consistency and purity required.

Table 2. Summary of value-added products for stone fruit waste.

Industry sector	Part of the fruit used	Processing required	Application	Degree of processing of fruit waste required to enter final product	Proportion of the fruit utilised
Beauty and personal care	Stone	Cleaned, kernel removed and milled	Exfoliant products and industrial hand cleaner	Low	Medium
	Kernel	Extraction of oil	Skin and hair moisturising and anti-aging products	Medium	Medium
	Kernel	Extraction of oil	Hair moisturising products	Medium	Medium
	Kernel	Extraction of oil	Skin treatment for acne, rosacea and psoriasis	Medium	Medium
	Skin and flesh, particularly thinned fruit	Extraction of antioxidants	Cleansing, protective, damage repair skin products including sheet masks	Medium	Low
	Mature skin and flesh	Extraction of ceramides	Anti-aging skin products	High	Low
Nutraceuticals	Thinned and mature skin and flesh	Extraction of antioxidants	Encapsulation as dietary supplements	High	Low
	Mature skin and flesh and pomace	Dried	Improved laxation and microbiome support	Low	High
Food	Kernel	Extraction of oil	Salad dressing, dips and sauces	Low-Medium	Medium
	Kernel	Extraction of oil	Frying and baking	Low-Medium	Medium
	Kernel	Extraction of oil	Replacement of saturated fat in bakery goods	Low-Medium	Medium
	Pomace	Dried	Partial replacement of saturated fat in bakery goods	Low	Medium

Industry sector	Part of the fruit used	Processing required	Application	Degree of processing of fruit waste required to enter final product	Proportion of the fruit utilised
	Kernel - defatted	Dried and milled	Replacement of flour in bread, noodles and pasta	Medium	Medium
	Pomace and mature flesh	Dried and milled	Extruded snacks and fruit leather	Medium	Medium
	Pomace	Dried and milled	Utilise natural pectin content as a thickener in jams, sauces, yoghurt and icecream	Low	Medium
	Pomace	Dried and milled	Bakery products	Low	Medium
	Mature flesh	Freeze dried and powdered	Snacking and powders for colour and antioxidant content	Low	High
Beverage	Mature flesh	Chopped or pureed, fresh or frozen	Smoothie packs and bombs	Low	High
	Mature flesh and skin	Chopped and dried	Cold water infusions and tea blends	Low	High
	Mature flesh and skin	Freeze dried and powdered	Bubble tea flavouring	Low	High
	Mature flesh and skin	Freeze dried and powdered, juice or puree	Kombucha and kefir flavouring	Low	High
	Mature flesh and skin	Freeze dried and powdered, juice or puree	Alcoholic and non alcoholic spirits, wine and cocktails	Low	High
Natural colourants	Mature flesh and skin	Extraction of anthocyanins or freeze dried and powdered	Food, pharmaceuticals and cosmetics	Medium	High

7. Patent summary

A summary of current patents (Table 3) that includes the use of stone fruit other than in the form of juice and stone fruit pomace is shown below.

An examination of the company websites from the listing below only provides limited information, particularly regarding stone fruit ingredients in any of their products. However, it is likely that many of these patents are active and associate with commercial products. For examples, Phoenix Eagle is an Australian biopharmaceutical company with products on the market for wound care treatment where peach pulp was reported as an ingredient(Graves and Ashby, 2008).

Table 3. Patent summary.

Industry sector	Part of the fruit used	Description	Patent number and applicant
Beauty and personal care	Peach and apricot kernel oil	Preparation of a skin moisturising gel.	US 11166885 B2 Colgate-Palmolive Company, US
	Peach and apricot kernel oil	Foaming oil cleanser with a high oil content.	US 10639270 B2 LOreal, France
	Peach flesh	Plant-based cough treatment flavoured with natural peach powder.	EP 3060224 B1 Aboca Spa Societ Agricola, Italy
	Peach flesh	Formulation of a base for topical creams.	US 2012/0308493 A1, Phoenix Eagle Company, Australia
Nutraceutical	Immature peach	Freeze-dried immature peach for the reduction of postprandial glycaemia.	EP 3831217 A1 New Generation Nutraceuticals, Italy
Food and beverage	Stone fruit pomace	Pre-treatment and particle and fibre size reduction of pomace for use in food products.	US 10334870 B2 Tropicana Products, US
	Stone fruit pomace	Production of pomace and whey (by product from cheese and yoghurt production high protein) by extrusion into a puffed snack food.	US 10524497 B2 Cornell University, US
	Stone fruit pomace	Extrusion of agro-food industry by products and protein concentrates into value-added foods.	US 10524497 B2 Cornell University, US
	Stone fruit flesh and pomace	Production of fruit or vegetable beverage enriched with fruit or vegetable fibre.	WO 2016038600 A1 Yissim Research Development Company
	Stone fruit flesh and pomace	Production of vegetable/fruit leather.	WO 2013/019936 A1 Nestec SA, Switzerland
	Stone fruit flesh	Production of a fermented, blended flour.	US 2018/0146688 A1 Green Spot Technologies Limited, New Zealand
	Stone fruit flesh	Frozen aerated product with no added emulsifiers or stabilisers.	US 8021706 B2 Good Humor Breyers Ice Cream (Unilever), US
	Plum flesh	Production of crunchy, puffed snacks from fruit	EP 3422861 B1, Ocean Spray Cranberries, US

Industry sector	Part of the fruit used	Description	Patent number and applicant
	Peach stone and apricot kernel	Preparing low gluten and low carbohydrate bakery goods	US 10555537 B2 Charrak Samir, Charrak Monika
	Peach skin and flesh	Production of small pop-able alcohol-containing spherical beads with peach as a natural favouring	US 10077419 B2 Hollenkamp; Steven J., US
	Peach flesh	Manufacturing method for biscuits containing peach dietary fibre and juice	CN 11014074 2A Chaohu University, China
	Peach flesh	Preparation of crispy peach chips	EP 0284042 A2 House Food Industrial Company, Japan
	Plum flesh and skin	Production of a naturally derived blue colourant for use in food products.	US 10750761 B2 Mars Incorporated, US

8. Conclusion

Stone fruit waste due to fruit immaturity, pest damage and unfavourable environmental conditions during the growing period as well as pomace from juicing and stones and skins from processing represents a significant loss of nutrients that could be used in value-added products that are currently in demand and would be appealing to consumers.

The skin and flesh of immature and mature fruit are a rich source of antioxidants that could have a wide range of applications. In beauty and personal care products antioxidants have been associated with anti-aging, skin repair and in purified forms, represent opportunities for consumers to personalise their skin care regime. For preventative health applications, the antioxidants would be of value encapsulated in supplement form. In the food and beverage industries, the skin and flesh could be used to improve the nutritional value of bakery goods, extruded snacks and as a thickener and source of dietary fibre in jams, sauces, yoghurt and ice cream. In the beverage sector, there are opportunities for the natural flavouring of a wide range of range of beverages including those that would appeal to health-conscious consumers. The anthocyanin content of the skin could be used as a natural colourant.

The oil for the kernel could be used in a range of beauty treatments, utilising the moisturising properties and for food applications as a replacement for saturated fats in bakery goods. The remnant kernel following oil extraction could be dried and ground to produce a flour that has a high protein content.

The stone fruit composition values provided are based on a range of varieties and growing conditions and so the composition of Victorian grown fruit needs to be assessed, particularly for products that would utilise the nutraceutical, protein or dietary fibre content of the fruit.

Each of the options provided uses a proportion of the fruit and so the stone fruit may need to undergo a number of processes to use substantial amounts. In addition to the processing rankings given, all aspects of transport costs need to be considered including maintaining the stone fruit waste in a form that is suitable for valorisation.

9. References

ABD EL-AAL, M. H., KHALIL, M. K. M. & RAHMA, E. H. 1986. Apricot kernel oil: Characterization, chemical composition and utilization in some baked products. *Food Chemistry,* 19**,** 287-298.

ACCORD. 2019. *BeadRecede* [Online]. Available: https://accord.asn.au/sustainability/beadrecede/ [Accessed 24th January 2022].

AKALıN, A., KESENKAS, H., DINKCI, N., UNAL, G., OZER, E. & KıNıK, O. 2018. Enrichment of probiotic ice cream with different dietary fibers: Structural characteristics and culture viability. *Journal of Dairy Science,* 101**,** 37-46.

AKDOGAN, H. & MCHUGH, T. H. 1999. Twin screw extrusion of peach puree: rheological properties and product characteristics. *Journal of Food Processing and Preservation,* 23**,** 285-305.

AKSOZ, E., KORKUT, O., AKSIT, D. & GOKBULUT, C. 2020. Vitamin E (α-, β+ γ-and δ-tocopherol) levels in plant oils. *Flavour and Fragrance Journal,* 35**,** 504-510.

ALPASLAN, M. & HAYTA, M. 2006. Apricot kernel: Physical and chemical properties. *Journal of the American Oil Chemists' Society,* 83**,** 469.

ANASTAS, P. & WARNER, J. 1998. *Green Chemistry Theory and Practice*, Oxford University Press: New York.

AYRES, S. & MIHAN, R. 1981. Acne vulgaris: therapy directed at pathophysiologic defects. *Cutis,* 28**,** 41-42.

BEHAGHEL DE BUEREN, J., HÉROGUEL, F., WEGMANN, C., DICK, G. R., BUSER, R. & LUTERBACHER, J. S. 2020. Aldehyde-assisted fractionation enhances lignin valorization in endocarp waste biomass. *ACS Sustainable Chemistry & Engineering,* 8**,** 16737-16745.

BENNETT, L. E., SINGH, D. P. & CLINGELEFFER, P. R. 2010. Micronutrient mineral and folate content of Australian and imported dried fruit products. *Critical Reviews in Food Science and Nutrition,* 51**,** 38-49.

BHASWANT, M., BROWN, L. & MATHAI, M. L. 2019. Queen Garnet plum juice and raspberry cordial in mildly hypertensive obese or overweight subjects: A randomized, double-blind study. *Journal of Functional Foods,* 56**,** 119-126.

BLANCO-PÉREZ, F., STEIGERWALD, H., SCHÜLKE, S., VIETHS, S., TODA, M. & SCHEURER, S. 2021. The dietary fiber pectin: Health benefits and potential for the treatment of allergies by modulation of gut microbiota. *Current Allergy and Asthma Reports,* 21**,** 1-19.

BOLARINWA, I. F., ORFILA, C. & MORGAN, M. R. A. 2014. Amygdalin content of seeds, kernels and food products commercially-available in the UK. *Food Chemistry,* 152**,** 133-139.

CARPENTIERI, S., SOLTANIPOUR, F., FERRARI, G., PATARO, G. & DONSÌ, F. 2021. Emerging green techniques for the extraction of antioxidants from agri-food by-products as promising ingredients for the food industry. *Antioxidants,* 10**,** 1417.

CHAMLI, D., BOOTELLO, M., BOUALI, I., JOUHRI, S., BOUKHCHINA, S. & MARTÍNEZ-FORCE, E. 2017. Chemical characterization and thermal properties of kernel oils from Tunisian peach and nectarine varieties of Prunus persica. *Grasas y Aceites,* 68**,** e211-e211.

CHANG, H.-K., SHIN, M.-S., YANG, H.-Y., LEE, J.-W., KIM, Y.-S., LEE, M.-H., KIM, J., KIM, K.-H. & KIM, C.-J. 2006. Amygdalin induces apoptosis through regulation of Bax and Bcl-2 expressions in human DU145 and LNCaP prostate cancer cells. *Biological and Pharmaceutical Bulletin,* 29**,** 1597-1602.

CHEN, Y., AL-GHAMDI, A. A., ELSHIKH, M. S., SHAH, M. H., AL-DOSARY, M. A. & ABBASI, A. M. 2020. Phytochemical profiling, antioxidant and HepG2 cancer cells' antiproliferation potential in the kernels of apricot cultivars. *Saudi Journal of Biological Sciences,* 27**,** 163-172.

CHEUNG, P. K. & FOK, L. 2016. Evidence of microbeads from personal care product contaminating the sea. *Marine Pollution Bulletin,* 109**,** 582-585.

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION. 2020. *Victoria's Nutraceutical Industry* [Online]. Available: https://www.csiro.au/en/work-with-us/services/consultancy-strategic-advice-services/csiro-futures/futures-reports/nutraceuticals-roadmap [Accessed 24th January 2022].

D'ELIA, L., BARBA, G., CAPPUCCIO, F. P. & STRAZZULLO, P. 2011. Potassium intake, stroke, and cardiovascular disease: a meta-analysis of prospective studies. *Journal of the American College of Cardiology,* 57**,** 1210-1219.

DHEN, N., BEN REJEB, I., BOUKHRIS, H., DAMERGI, C. & GARGOURI, M. 2018. Physicochemical and sensory properties of wheat- Apricot kernels composite bread. *LWT - Food Science and Technology,* 95**,** 262-267.

DURMAZ, G., KARABULUT, I., TOPÇU, A., ASILTÜRK, M. & KUTLU, T. 2010. Roasting-related changes in oxidative stability and antioxidant capacity of apricot kernel oil. *Journal of the American Oil Chemists' Society,* 87**,** 401-409.

EL-AAL, M. H. A., HAMZA, M. A. & RAHMA, E. H. 1986. In vitro digestibility, physico-chemical and functional properties of apricot kernel proteins. *Food Chemistry,* 19**,** 197-211.

EL-DEMERY, M. E. & ELSANAT, S. 2010. Influence of apricot kernel flour addition on sensory characteristics of spaghetti. *Egyptian Journal of Food Science,* 38**,** 49-65.

EYIDEMIR, E. & HAYTA, M. 2009. The effect of apricot kernel flour incorporation on the physicochemical and sensory properties of noodle. *African Journal of Biotechnology,* 8.

FAYET-MOORE, F., CASSETTARI, T., TUCK, K., MCCONNELL, A. & PETOCZ, P. 2018. Dietary fibre intake in Australia. Paper I: associations with demographic, socio-economic, and anthropometric factors. *Nutrients,* 10**,** 599.

FOOD STANDARDS AUSTRALIA NEW ZEALAND. 2015. *Hydrocyanic acid in apricot kernels and other foods* [Online]. Available: https://www.foodstandards.gov.au/code/proposals/Documents/P1016-AppR.pdf [Accessed 24th January 2022].

FOOD STANDARDS AUSTRALIA NEW ZEALAND. 2017. *Apricot kernels (raw)* [Online]. Available: https://www.foodstandards.gov.au/consumer/safety/pages/apricot-kernels-raw.aspx [Accessed 24th January 2022].

FRANCIS, F. J. & MARKAKIS, P. C. 1989. Food colorants: anthocyanins. *Critical Reviews in Food Science & Nutrition,* 28**,** 273-314.

FRATIANNI, F., OMBRA, M. N., D'ACIERNO, A., CIPRIANO, L. & NAZZARO, F. 2018. Apricots: biochemistry and functional properties. *Current Opinion in Food Science,* 19**,** 23-29.

FROYEN, E. & BURNS-WHITMORE, B. 2020. The effects of linoleic acid consumption on lipid risk markers for cardiovascular disease in healthy individuals: A review of human intervention trials. *Nutrients,* 12**,** 2329.

GIDLEY, M. J. & YAKUBOV, G. E. 2019. Functional categorisation of dietary fibre in foods: Beyond 'soluble'vs 'insoluble'. *Trends in Food Science & Technology,* 86**,** 563-568.

GIL, M. I., TOMÁS-BARBERÁN, F. A., HESS-PIERCE, B. & KADER, A. A. 2002. Antioxidant capacities, phenolic compounds, carotenoids, and vitamin C contents of nectarine, peach, and plum cultivars from California. *Journal of Agricultural and Food Chemistry,* 50**,** 4976-4982.

GRAVES, N. & ASHBY, A. 2008. The use of OPAL001 filtrate and cream in the treatment of chronic pressure ulcers. *Wound Practice & Research: Journal of the Australian Wound Management Association,* 16**,** 22-29.

GRIGELMO-MIGUEL, N., CARRERAS-BOLADERAS, E. & MARTÍN-BELLOSO, O. 1999. Development of high-fruit-dietary-fibre muffins. *European Food Research and Technology,* 210**,** 123-128.

GRIGELMO-MIGUEL, N., CARRERAS-BOLADERAS, E. & MARTÍN-BELLOSO, O. 2001. Influence of the addition of peach dietary fiber in composition, physical properties and acceptability of reduced-fat muffins. *Food Science and Technology International,* 7**,** 425-431.

GRIGELMO-MIGUEL, N. & MARTIN-BELLOSO, O. 2000. The quality of peach jams stabilized with peach dietary fiber. *European Food Research and Technology,* 211**,** 336-341.

GRIGELMO-MIGUEL, N. & MARTíN-BELLOSO, O. 1999a. Comparison of dietary fibre from by-products of processing fruits and greens and from cereals. *LWT-Food Science and Technology,* 32**,** 503-508.

GRIGELMO-MIGUEL, N. & MARTíN-BELLOSO, O. 1999b. Influence of fruit dietary fibre addition on physical and sensorial properties of strawberry jams. *Journal of Food Engineering,* 41**,** 13-21.
HARGUINDEGUY, M. & FISSORE, D. 2020. On the effects of freeze-drying processes on the nutritional properties of foodstuff: A review. *Drying Technology,* 38**,** 846-868.
HEIDARI, A. 2016. Measurement of the amount of vitamin D2 (ergocalciferol), vitamin D3 (cholecalciferol) and absorbable calcium (Ca2+), iron (II)(Fe2+), magnesium (Mg2+), phosphate (PO4–) and zinc (Zn2+) in apricot using high–performance liquid chromatography (HPLC) and spectroscopic techniques. *Journal of Biometrics and Biostatistics,* 7**,** 292.
HERNÁNDEZ-HERRERO, J. A. & FRUTOS, M. J. 2014. Colour and antioxidant capacity stability in grape, strawberry and plum peel model juices at different pHs and temperatures. *Food Chemistry,* 154**,** 199-204.
HUNT, C. F., LIN, W. H. & VOULVOULIS, N. 2021. Evaluating alternatives to plastic microbeads in cosmetics. *Nature Sustainability,* 4**,** 366-372.
KAMEL, B. & KAKUDA, Y. 1992. Characterization of the seed oil and meal from apricot, cherry, nectarine, peach and plum. *Journal of the American Oil Chemists' Society,* 69**,** 492-494.
KASAPOGLU, E. D., KAHRAMAN, S. & TORNUK, F. 2020. Apricot juice processing byproducts as sources of value-added compounds for food industry. *European Food Science and Engineering,* 1**,** 18-23.
KATAYAMA, S., OGAWA, H. & NAKAMURA, S. 2011. Apricot carotenoids possess potent anti-amyloidogenic activity in vitro. *Journal of Agricultural and Food Chemistry,* 59**,** 12691-12696.
KOIKEDA, T., TOKUDOME, Y., OKAYASU, M., KOBAYASHI, Y., KURODA, K., YAMAKAWA, J., NIU, K., MASUDA, K. & SAITO, M. 2017. Effects of peach (Prunus persica)-derived glucosylceramide on the human skin. *Immunology, Endocrine & Metabolic Agents in Medicinal Chemistry,* 17**,** 56-70.
KUMAR, K., SRIVASTAV, S. & SHARANAGAT, V. S. 2021. Ultrasound assisted extraction (UAE) of bioactive compounds from fruit and vegetable processing by-products: A review. *Ultrasonics Sonochemistry,* 70**,** 105325.
LAL, B. & SINGH, K. 2008. Indigenous herbal remedies used to cure skin disorders by the natives of Lahaul-Spiti in Himachal Pradesh. *Indian Journal of Traditional Knowledge,* 7.
LEA, M. A., IBEH, C., VIZZOTTO, M., CISNEROS-ZEVALLOS, L., BYRNE, D. H., OKIE, W. R. & MOYER, M. P. 2008. Inhibition of growth and induction of differentiation of colon cancer cells by peach and plum phenolic compounds. *Anticancer Research,* 28**,** 2067-2076.
LEE, H. H., AHN, J. H., KWON, A. R., LEE, E. S., KWAK, J. H. & MIN, Y. H. 2014. Chemical composition and antimicrobial activity of the essential oil of apricot seed. *Phytotherapy Research,* 28**,** 1867-1872.
LI, K., YANG, W., LI, Z., JIA, W., LI, J., ZHANG, P. & XIAO, T. 2016. Bitter apricot essential oil induces apoptosis of human HaCaT keratinocytes. *International Immunopharmacology,* 34**,** 189-198.
LIMA, B. N. B., LIMA, F. F., TAVARES, M. I. B., COSTA, A. M. M. & PIERUCCI, A. P. T. R. 2014. Determination of the centesimal composition and characterization of flours from fruit seeds. *Food Chemistry,* 151**,** 293-299.
MALDONADO, R. R., AGUIAR-OLIVEIRA, E., KAMIMURA, E. S. & MAZALLI, M. R. 2019. Kefir and Kombucha Beverages: New Substrates and Nutritional Characteristics. *Fermented Food Products.* CRC Press.
MANSOUR, A. I., AHMED, M. A., ELFARUK, M. S., ALSALEEM, K. A., HAMMAM, A. R. & EL-DERWY, Y. M. 2021. A novel process to improve the characteristics of low-fat ice cream using date fiber powder. *Food Science & Nutrition,* 9**,** 2836-2842.
MAPHOSA, Y. & JIDEANI, V. A. 2016. Dietary fiber extraction for human nutrition—A review. *Food Reviews International,* 32**,** 98-115.
MEENA, N. K., CHOUDHARY, K., NEGI, N., MEENA, V. S. & GUPTA, V. 2021. Nutritional Composition of Stone Fruits. *Production Technology of Stone Fruits.* Springer.

MICHALAK, M. 2018. The use of carrier oils in aromatherapy massage and their effect on skin. *Archives of Physiotherapy & Global Researches,* 22.
MILALA, J., KOSMALA, M., SÓJKA, M., KOŁODZIEJCZYK, K., ZBRZEŹNIAK, M. & MARKOWSKI, J. 2013. Plum pomaces as a potential source of dietary fibre: composition and antioxidant properties. *Journal of Food Science and Technology,* 50**,** 1012-1017.
MITSUISHI, T., SHIMODA, T., MITSUI, Y., KURIYAMA, Y. & KAWANA, S. 2004. The effects of topical application of phytonadione, retinol and vitamins C and E on infraorbital dark circles and wrinkles of the lower eyelids. *Journal of Cosmetic Dermatology,* 3**,** 73-75.
MOKRANI, A. & MADANI, K. 2016. Effect of solvent, time and temperature on the extraction of phenolic compounds and antioxidant capacity of peach (Prunus persica L.) fruit. *Separation and Purification Technology,* 162**,** 68-76.
MORDOR INTELLIGENCE. 2021a. *Australia Beauty and Personal Care Products Market - Growth, Trends, And Forecasts (2021 - 2026)* [Online]. Available: https://www.mordorintelligence.com/industry-reports/australia-beauty-and-personal-care-products-market-industry [Accessed 24th January 2022].
MORDOR INTELLIGENCE. 2021b. *Australia nutraceuticals market - growth, trends, COVID-19 impact, and forecasts (2022 - 2027)* [Online]. Available: https://www.mordorintelligence.com/industry-reports/australia-nutraceutical-market [Accessed 24th January 2022].
MORDOR INTELLIGENCE. 2021c. *Natural food colourants market - growth, trend, COVID-19 impact and forecast (2022 - 2027).* [Online]. Available: https://www.mordorintelligence.com/industry-reports/global-natural-food-colorants-market [Accessed 24th January 2022].
NAKAGAWA, A., SAWADA, T., OKADA, T., OHSAWA, T., ADACHI, M. & KUBOTA, K. 2007. New antineoplastic agent, MK615, from UME (a Variety of) Japanese apricot inhibits growth of breast cancer cells in vitro. *The breast journal,* 13**,** 44-49.
NETZEL, M., FANNING, K., NETZEL, G., ZABARAS, D., KARAGIANIS, G., TRELOAR, T., RUSSELL, D. & STANLEY, R. 2012. Urinary excretion of antioxidants in healthy humans following queen garnet plum juice ingestion: A new plum variety rich in antioxidant compounds. *Journal of Food Biochemistry,* 36**,** 159-170.
NORATTO, G., PORTER, W., BYRNE, D. & CISNEROS-ZEVALLOS, L. 2014. Polyphenolics from peach (Prunus persica var. Rich Lady) inhibit tumor growth and metastasis of MDA-MB-435 breast cancer cells in vivo. *The Journal of Nutritional Biochemistry,* 25**,** 796-800.
NÚÑEZ-DECAP, M., WECHSLER-PIZARRO, A. & VIDAL-VEGA, M. 2021. Mechanical, physical, thermal and morphological properties of polypropylene composite materials developed with particles of peach and cherry stones. *Sustainable Materials and Technologies,* 29**,** e00300.
NUTRAFRUIT. 2021. *The Plum Backed By Research* [Online]. Available: https://queengarnet.com/ [Accessed 24th January 2022].
OKADA, T., SAWADA, T., OSAWA, T., ADACHI, M. & KUBOTA, K. 2007. A novel anti-cancer substance, MK615, from ume, a variety of Japanese apricot, inhibits growth of hepatocellular carcinoma cells by suppressing Aurora A kinase activity. *Hepato-gastroenterology,* 54**,** 1770-1774.
ÖZBOY-ÖZBAŞ, Ö., SEKER, I. T. & GÖKBULUT, I. 2010. Effects of resistant starch, apricot kernel flour, and fiber-rich fruit powders on low-fat cookie quality. *Food Science and Biotechnology,* 19**,** 979-986.
OZCAN, M. M. 2010. Properties of apricot kernel and oils as fruit juice processing waste. *Food and Nutrition Sciences,* 1**,** 7.
PAGÁN, J., IBARZ, A., LLORCA, M., PAGÁN, A. & BARBOSA-CÁNOVAS, G. V. 2001. Extraction and characterization of pectin from stored peach pomace. *Food Research International,* 34**,** 605-612.
PARK, H.-J., PARK, K.-K., HWANG, J.-K., CHUNG, W.-Y., KIM, G.-D., LEE, M.-A. & LEE, S.-K. 2012. Protective effects of Prunus persica flesh extract (PPFE) on UV-induced oxidative stress and

matrix metalloproteinases expression in human skin cells. *Natural Product Sciences,* 18**,** 52-59.
PASTOR, N., COLLADO, M. C. & MANZONI, P. 2021. Phytonutrient and Nutraceutical Action against COVID-19: Current Review of Characteristics and Benefits. *Nutrients,* 13**,** 464.
PAVLOVIĆ, N., VIDOVIĆ, S., VLADIĆ, J., POPOVIĆ, L., MOSLAVAC, T., JAKOBOVIĆ, S. & JOKIĆ, S. 2018. Recovery of tocopherols, amygdalin, and fatty acids from apricot kernel oil: Cold pressing versus supercritical carbon dioxide. *European Journal of Lipid Science and Technology,* 120**,** 1800043.
PRASAD, K. N. & BONDY, S. C. 2019. Dietary fibers and their fermented short-chain fatty acids in prevention of human diseases. *Bioactive Carbohydrates and Dietary Fibre,* 17**,** 100170.
QUILES, A., CAMPBELL, G. M., STRUCK, S., ROHM, H. & HERNANDO, I. 2018. Fiber from fruit pomace: A review of applications in cereal-based products. *Food Reviews International,* 34**,** 162-181.
RAHMA, E. H. & EL-AAL, M. H. A. 1988. Chemical characterization of peach kernel oil and protein: Functional properties, in vitro digestibility and amino acids profile of the flour. *Food Chemistry,* 28**,** 31-43.
REDONDO, D., ARIAS, E., ORIA, R. & VENTURINI, M. E. 2017. Thinned stone fruits are a source of polyphenols and antioxidant compounds. *Journal of the Science of Food and Agriculture,* 97**,** 902-910.
REDONDO, D., GIMENO, D., CALVO, H., VENTURINI, M. E., ORIA, R. & ARIAS, E. 2021. Antioxidant activity and phenol content in different tissues of stone fruits at thinning and at commercial maturity stages. *Waste and Biomass Valorization,* 12**,** 1861-1875.
REDONDO, D., VENTURINI, M. E., LUENGO, E., RASO, J. & ARIAS, E. 2018. Pulsed electric fields as a green technology for the extraction of bioactive compounds from thinned peach by-products. *Innovative Food Science & Emerging Technologies,* 45**,** 335-343.
REES, J., RADAVELLI BAGATINI, S., LO, J., HODGSON, J. M., CHRISTOPHERSEN, C. T., DALY, R. M., MAGLIANO, D. J., SHAW, J. E., SIM, M., BONDONNO, C. P., BLEKKENHORST, L. C., DICKSON, J. M., LEWIS, J. R. & DEVINE, A. 2021. Association between fruit and vegetable intakes and mental health in the Australian diabetes, obesity and lifestyle cohort. *Nutrients,* 13**,** 1447.
ROKNUL AZAM, S. M., ZHANG, M., LAW, C. L. & MUJUMDAR, A. S. 2019. Effects of drying methods on quality attributes of peach (Prunus persica) leather. *Drying Technology,* 37**,** 341-351.
ROSADO, C. P., ROSA, V. H. C., MARTINS, B. C., SOARES, A. C., ALMO, A., MONTEIRO, E. B., MULDER, A. D. R. P., MOURA-NUNES, N. & DALEPRANE, J. B. 2021. Green banana flour supplementation improves obesity-associated systemic inflammation and regulates gut microbiota profile in mice fed high-fat diets. *Applied Physiology, Nutrition, and Metabolism,* 46**,** 1469-1475.
SAKURAI, K., SHEN, C., SHIRAISHI, I., INAMURA, N. & HISATSUNE, T. 2021. Consumption of oleic acid on the preservation of cognitive functions in Japanese elderly individuals. *Nutrients,* 13**,** 284.
SANTHAKUMAR, A. B., KUNDUR, A. R., FANNING, K., NETZEL, M., STANLEY, R. & SINGH, I. 2015. Consumption of anthocyanin-rich Queen Garnet plum juice reduces platelet activation related thrombogenesis in healthy volunteers. *Journal of Functional Foods,* 12**,** 11-22.
SARKAR, P. & CHOUDHURY, G. S. 2021. Peach pomace processing using twin screw extrusion. *Journal of Microbiology, Biotechnology and Food Sciences,* 2021**,** 279-285.
SEKER, I., OZBOY-OZBAS, O., GOKBULUT, I., OZTURK, S. & KOKSEL, H. 2010. Utilization of apricot kernel flour as fat replacer in cookies. *Journal of Food Processing and Preservation,* 34**,** 15-26.
SERRA, S., ANTHONY, B., MASIA, A., GIOVANNINI, D. & MUSACCHI, S. 2020. Determination of biochemical composition in peach (Prunus persica L. Batsch) accessions characterized by different flesh color and textural typologies. *Foods,* 9**,** 1452.
SHARMA, P., TILAKRATNE, B. & GUPTA, A. 2010. Utilization of wild apricot kernel press cake for extraction of protein isolate. *Journal of Food Science and Technology,* 47**,** 682-685.

SINGH, S. & KULSHRESTHA, K. 2016. Peach Juice and Pomace Powder; Nutritive Value and Use of Pomace Powder in Biscuits. *International Journal of Food Science and Technology (IJFST) Vol,* 6**,** 5-16.

SODEIFIAN, G. & SAJADIAN, S. A. 2021. Antioxidant capacity, physicochemical properties, thermal behavior, and oxidative stability of nectarine (Prunus persica var. nucipersica) kernel oil. *Journal of Food Processing and Preservation,* 45**,** e15198.

SOUKOULIS, C., LEBESI, D. & TZIA, C. 2009. Enrichment of ice cream with dietary fibre: Effects on rheological properties, ice crystallisation and glass transition phenomena. *Food Chemistry,* 115**,** 665-671.

SOUTHORN, P. A. & POWIS, G. 1988. Free radicals in medicine. II. Involvement in human disease. *Mayo Clinic Proceedings,* 63**,** 390-408.

STEVANATO, R., BERTELLE, M. & FABRIS, S. 2014. Photoprotective characteristics of natural antioxidant polyphenols. *Regulatory Toxicology and Pharmacology,* 69**,** 71-77.

TERÉS, S., BARCELÓ-COBLIJN, G., BENET, M., ÁLVAREZ, R., BRESSANI, R., HALVER, J. E. & ESCRIBÁ, P. V. 2008. Oleic acid content is responsible for the reduction in blood pressure induced by olive oil. *Proceedings of the National Academy of Sciences,* 105**,** 13811.

THERAPEUTIC GOODS ADMINISTRATION. 2021. *Notice of interim decisions on proposed amendments to the Poisons Standard - ACMS, ACCS and Joint ACMS-ACCS meetings, November 2020, 2.1 Amygdalin and hydrocyanic acid* [Online]. Australian Government, Department of Health. Available: https://www.tga.gov.au/book-page/21-amygdalin-and-hydrocyanic-acid [Accessed 24th January 2022].

U.S. NATIONAL LIBRARY OF MEDICINE. *ClinicalTrials.gov* [Online]. Available: https://clinicaltrials.gov/ct2/home [Accessed 24th January 2022].

VÁSQUEZ-VILLANUEVA, R., MARINA, M. L. & GARCÍA, M. C. 2015. Revalorization of a peach (Prunus persica (L.) Batsch) byproduct: Extraction and characterization of ACE-inhibitory peptides from peach stones. *Journal of Functional Foods,* 18**,** 137-146.

VÁSQUEZ-VILLANUEVA, R., ORELLANA, J. M., MARINA, M. L. & GARCÍA, M. C. 2019. Isolation and characterization of angiotensin converting enzyme inhibitory peptides from peach seed hydrolysates: In vivo assessment of antihypertensive activity. *Journal of Agricultural and Food Chemistry,* 67**,** 10313-10320.

VILLALVA, F. J., CRAVERO BRUNERI, A. P., VINDEROLA, G., GONCALVEZ DE OLIVEIRA, E., PAZ, N. F. & RAMÓN, A. N. 2017. Formulation of a peach ice cream as potential symbiotic food. *Food Science and Technology,* 37**,** 456-461.

VIZZOTTO, M., PORTER, W., BYRNE, D. & CISNEROS-ZEVALLOS, L. 2014. Polyphenols of selected peach and plum genotypes reduce cell viability and inhibit proliferation of breast cancer cells while not affecting normal cells. *Food Chemistry,* 164**,** 363-370.

VLADIC, J., GAVARIC, A., JOKIC, S., PAVLOVIC, N., MOSLAVAC, T., POPOVIC, L., MATIAS, A., AGOSTINHO, A., BANOZIC, M. & VIDOVIC, S. 2020. Alternative to conventional edible oil sources: cold pressing and supercritical CO_2 extraction of plum (Prunus Domestica L.) kernel seed. *Acta Chimica Slovenica,* 67**,** 778-784.

WAGHMARE, R. B., CHOUDHARY, P., MOSES, J. A., ANANDHARAMAKRISHNAN, C. & STAPLEY, A. G. F. 2021. Trends in approaches to assist freeze-drying of food: A cohort study on innovations. *Food Reviews International***,** 1-22.

WU, H., SHI, J., XUE, S., KAKUDA, Y., WANG, D., JIANG, Y., YE, X., LI, Y. & SUBRAMANIAN, J. 2011. Essential oil extracted from peach (Prunus persica) kernel and its physicochemical and antioxidant properties. *LWT-Food Science and Technology,* 44**,** 2032-2039.

WU, X., BEECHER, G. R., HOLDEN, J. M., HAYTOWITZ, D. B., GEBHARDT, S. E. & PRIOR, R. L. 2006. Concentrations of anthocyanins in common foods in the United States and estimation of normal consumption. *Journal of Agricultural and Food Chemistry,* 54**,** 4069-4075.

YAO, J. L., ZHANG, Q. A. & LIU, M. J. 2021. Effects of apricot kernel skins addition and ultrasound treatment on the properties of the dough and bread. *Journal of Food Processing and Preservation*, e15611.