Food Chemistry 370 (2022) 131315

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Valorization of kiwi agricultural waste and industry by-products by recovering bioactive compounds and applications as food additives: A circular economy model

F. Chamorro [a,1], M. Carpena [a,1], M. Fraga-Corral [a,b], J. Echave [a], Muhammad Shahid Riaz Rajoka [c], Francisco J. Barba [d], Hui Cao [a], Jianbo Xiao [a,e], M.A. Prieto [a,b], J. Simal-Gandara [a,*]

[a] Universidade de Vigo, Nutrition and Bromatology Group, Department of Analytical Chemistry and Food Science, Faculty of Science, E-32004 Ourense, Spain
[b] Centro de Investigação de Montanha (CIMO), Instituto Politécnico de Bragança, Campus de Santa Apolonia, 5300-253 Bragança, Portugal
[c] Food and Feed Immunology Group, Laboratory of Animal Food Function, Graduate School of Agricultural Science, Tohoku University, Sendai 980-8572, Japan
[d] Nutrition and Food Science Area, Preventive Medicine and Public Health, Food Science, Toxicology and Fo-rensic Medicine Department, Universitat de València, Faculty of Pharmacy, Avda, Vicent Andrés Estellés, s/n, Burjassot 46100, València, Spain
[e] International Reserch Center for Food Nutrition and Safety, Jiangsu University, Zhenjiang 212013, China

ARTICLE INFO

Keywords:
Kiwi residues
Circular economy
Food applications
Phenolic compounds
Vitamins

ABSTRACT

Currently, agricultural production generates large amounts of organic waste, both from the maintenance of farms and crops (agricultural wastes) and from the industrialization of the product (food industry waste). In the case of *Actinidia* cultivation, agricultural waste groups together leaves, flowers, stems and roots while food industry by-products are represented by discarded fruits, skin and seeds. All these matrices are now underexploited and so, they can be revalued as a natural source of ingredients to be applied in food, cosmetic or pharmaceutical industries. Kiwifruit composition (phenolic compounds, volatile compounds, vitamins, minerals, dietary fiber, etc.) is an outstanding basis, especially for its high content in vitamin C and phenolic compounds. These compounds possess antioxidant, anti-inflammatory or antimicrobial activities, among other beneficial properties for health, but stand out for their digestive enhancement and prebiotic role. Although the biological properties of kiwi fruit have been analyzed, few studies show the high content of compounds with biological functions present in these by-products. Therefore, agricultural and food industry wastes derived from processing kiwi are regarded as useful matrices for the development of innovative applications in the food (pectins, softeners, milk coagulants, and colorants), cosmetic (ecological pigments) and pharmaceutical industry (fortified, functional, nutraceutical, or prebiotic foods). This strategy will provide economic and environmental benefits, turning this industry into a sustainable and environmentally friendly production system, promoting a circular and sustainable economy.

1. Introduction

Kiwi is the best known fruit of the genus *Actinidia* (Actinidiaceae family) which has become a very popular product throughout the world due to its nutritional and organoleptic properties together with its health benefits (Latocha, 2017; Nishiyama et al., 2004; Pinto, Delerue-matos, & Rodrigues, 2020). Originally from China, this genus is widely distributed, from regions with a tropical climate to areas with temperate-cold climates (Huang, 2016; Pinto et al., 2020). In general, the plants of this genus are characterized by woody vines that can wildly grow up to 100 years and reach 5–7 m tall. The fruit presents a high variability in terms of mass, shape, skin and pulp color, ripening time, presence or absence of hairiness, and flavor (Wojdyło, Nowicka, Oszmiański, & Golis, 2017). They are mostly oval, oblong, or cylindrical with a mass between 50 and 70 g, although in some cases they can exceed 200 g. The skin can vary between green, brown, orange, red or purple while the pulp is green, yellow or red (Henare, 2015; Huang, 2016). The ripening of the fruit, from the flower fall-down until the kiwi reaches its desired maturity can

* Corresponding author.
E-mail address: jsimal@uvigo.es (J. Simal-Gandara).
[1] These authors contributed equally to the publication.

https://doi.org/10.1016/j.foodchem.2021.131315
Received 28 July 2021; Received in revised form 29 September 2021; Accepted 1 October 2021
Available online 6 October 2021

last between 100 and 210 days, depending on the species, which is essential for the fruits to reach their optimal chemical composition and their corresponding characteristic flavor (Richardson, Ansell, & Drummond, 2018).

This genus comprises more than 70 species, of which three are of greatest commercial interest commonly known as yellow (*Actinidia chinensis*), green (*A. deliciosa*) and resistant (*A. arguta*, also known as kiwiberry) (Giangrieco et al., 2016), which can be differentiated mainly by their morphological characteristics. On the one hand, the fruit of *A. deliciosa* shows a dull and hairy brown skin while the pulp is bright green, translucent contrasting with the white color of the nucleus (placenta) and black seeds. On the other hand, the skin of the fruits of *A. chinensis* is glabrous and its interior is, in most cases, yellow. In addition, they have a bulge at one of their ends, providing them with a characteristic shape (Nishiyama, 2007). Lastly, the size of *A. arguta* kiwifruits are much smaller and usually weight around 10–15 g. Its skin is thin, hairless, edible and sweet, while its pulp is usually green or red. Regarding its maturation, *A. arguta* is normally collected 100–110 days after pollination, while *A. chinensis* and *A. deliciosa* must take between 180 and 210 days (Henare, 2015; Huang, 2016). *A. arguta* is the species with the greatest geographic range of cultivation whereas *A. deliciosa* and *A. chinensis* present more growth problems (Pinto et al., 2020). Regarding its composition, kiwifruits show slight variations between species. In general, they stand out for their high vitamin C (ascorbic acid) content in addition to their high levels of vitamin E, fiber, potassium, and folic acid (Pérez-Burillo, Oliveras, Quesada, Rufián-Henares, & Pastoriza, 2018; Richardson et al., 2018). They are also considered a source of carbohydrates, proteins, phenolic compounds and carotenoids such as lutein (X. He et al., 2019; Henare, 2015), which are known to exert different bioactivities, including antioxidant, anti-inflammatory or antimicrobial activities as well as probiotic effects, among others (Pérez-Burillo et al., 2018; Pinto et al., 2020; Richardson et al., 2018). Among them, the antioxidant capacity is the most studied, given its correlation with the content of kiwifruits in vitamin C and phenolic compounds (Leontowicz et al., 2016; Park et al., 2014).

The kiwifruit is originally from China, where its flowers were used for ornamental purposes whereas the fresh fruit was used for the treatment of certain disorders such as digestive problems, rheumatism, dyspepsia, hemorrhoids or cancer therapy (Henare, 2015; Pinto et al., 2020). However, the kiwifruit industry experienced its maximum growth due to the success of the cultivar ''Hayward'' of the species *A. chinensis* var. *Deliciosa*, which was later joined by the cultivar ''Hort16A'', launched on the market by the ''ZESPRITM GOLD Kiwifruit'' and more recently, the species *A. arguta* (Huang, 2016; Nishiyama, 2007). The latest data show that world kiwifruit production is around 4 million tons per year, Asia being the main producer and China, standing as the region responsible for half of world kiwifruit production (FAO, 2020; Pérez-Burillo et al., 2018). Particularly, although this fruit is mostly consumed raw, it is also used for the production of juices, wines, jams or ice creams, among other products (Nishiyama et al., 2004). This industrialization generates kiwifruit residues, especially seeds, skin and kiwifruit discards, that have arisen interest in the industry due to their bioactive compounds, high content of carotenoids, triterpenes and polyphenols (Dias et al., 2020). In addition, these and other bioactive compounds can be obtained from the agricultural waste generated because of the cultivation exploitation (flowers, leaves, stems, seeds), among which minerals, vitamins, carbohydrates, and even volatile substances stand out. Therefore, these residues have great potential as source of biomolecules with recognized health-promoting properties for food products applications (Latocha, 2017; Pinto et al., 2020).

Furthermore, in recent years, the interest of consumers for more natural and healthy products has driven the research and development of natural compounds with bioactive properties that can replace synthetic additives (Jimenez-Lopez et al., 2020). The use of fruit by-products is one of the global trends to address sustainability in food production (Kheirkhah, Baroutian, & Young, 2019). In addition, the high awareness of society to adopt preventive health measures, such as a healthy and balanced diet and the use of food supplements with positive effects, has led to an increase in demand for these new natural additives with bioactive capacities (Wojdyło et al., 2017). These new natural compounds must be novel and have an added value as well as showing fewer side effects than synthetic ingredients (Traka & Mithen, 2011). So, the current trend is aimed at using the residues derived from agricultural production as matrices to obtain bioactive compounds of interest to the industry, integrating the concepts of agriculture, industrial production and circular economy from a sustainable point of view (Jimenez-Lopez et al., 2020; Toop et al., 2017).

On these bases, the main aim of this work is to provide an overview of the nutritional and chemical composition together with the bioactive properties of the fruits of the different commercial varieties of the genus *Actinidia* and the residues derived from its production and processing. Knowing in-depth the chemical composition of these matrices and their bioactivities is essential to evaluate their potency to revalue them for their use in industrial applications. Among the multiple possibilities, kiwi residues might be re-used as natural additives or functional ingredients in the food and pharmaceutical industries.

2. Kiwi food industry by-products

In 2019, kiwi cultivation occupied a surface of ~ 270 × 103 ha around the world to which Europe contributed with ~ 43 × 103 ha (15% of the global distribution). Regarding the kiwi production it was globally quantified in ~ 4.5×10^6 tons to which Europe provided more than 20% (~1×10^6 tons) of the total production (FAO, 2020). It is well known that some geographical areas are more productive due to their climatic conditions, being one of the southern countries of Europe. This higher rate of production also implies an overproduction of derived wastes. Currently, data about food loss and waste is very scarce however, it has been estimated that more than 20% of the vegetables and fruit production becomes waste (García-Oliveira, Fraga-Corral, Pereira, Prieto, & Simal-Gandara, 2020). In kiwi production, this percentage turns into ~ 1×10^6 tons of annual and global waste. In this sense, there are two main international concerns, one is the negative impact that the increasing generation of food waste involves (carbon footprint) and another is the urgent need of improving the throughput of the production systems to make them capable of feeding the rising world population (Almond, Grooten, & Petersen, 2020; FAO, 2018). These two global concerns are triggering a shift in the production models. Among the adopted strategies, the 'circular economy' is the most appealed one. The concept 'end-of-life' is replaced by reducing, alternatively reusing, recycling, and recovering which should entail a direct reduction in the waste produced. Hence this model is expected to provide sustainable development, enhance environmental quality, and economic prosperity (Kirchherr, Reike, & Hekkert, 2017). To reduce these losses and improve the efficiency of the production of the kiwi, food industry has taken advantage of the broad nutritional benefits and organoleptic properties of this fruit to design various ways to transform its by-products into, for example, juices, wines, jams, ice creams, and even as pastry ingredients and confectionery products (López-Sobaler, Aparicio Vizuete, & Ortega Anta, 2016). From this processing, bagasse, skin, and seeds are essentially obtained as waste. Additionally, the kiwi industry generates another type of waste, the fruit that is not acceptable for marketing, or its use as part of other foods, due to the strict quality standards established. Various studies indicate that all these fractions are rich in bioactive compounds such as vitamins, minerals and phenolic compounds (Deng et al., 2016). These biomolecules are interesting for food, pharmaceutical and cosmetic industries, and their reutilization would promote a circular and sustainable economy around the kiwi industry. This strategy is relevant to harmonize with the sustainable development goals (SDG), specifically with the objective of minimizing food waste, reducing losses in production and in supply chains (Leiva Sajuria, 2014). To maximize the environmental benefits of reusing these wastes, it is required the application of green extraction techniques to obtain optimal production yields in an ecological and economic way. Besides, the correct adaptation of the raw material to an adequate final application, achieves more efficient and sustainable processes (Dias et al., 2020) The bioactive compounds recovered with these extraction techniques show a wide commercial potential, in addition to a better cost-benefit ratio, decreasing food loss, improving energy consumption and reducing environmental pollution (Jimenez-Lopez et al., 2020).

2.1. Kiwi fruit discarded: Nutritional and chemical composition

The nutritional composition of the Kiwi is characterized by a low contribution of energy, carbohydrates, proteins, and lipids, and a high content of water, fiber, minerals and vitamins but also interesting biomolecules. The nutritional composition of the three most currently cultivated species is summarized in Fig. 1. Chemical determinations displayed in this figure were made on the pulp of mature fruits, since most kiwis, except *A. arguta*, are eaten without skin (Pérez-Burillo et al., 2018; Richardson et al., 2018).

Regarding the macronutrients, kiwis are low in sugars, being attractive for using in a diet low in fermentable oligosaccharides, disaccharides, monosaccharides, and polyols (FODMAP) (Chen, Offereins, Mulder, Frampton, & Gearry, 2018). Among the sugars present in kiwi, fructose and glucose stand out, in the case of *A. deliciosa* and *A. chinensis*, and sucrose in the case of *A. arguta* (Fig. 1) (Latocha, Łata, & Stasiak, 2015; Pérez-Burillo et al., 2018). Kiwi provides low protein intake, however the most abundant ones, actinidin and kiwellin, both rich in cysteine, have been described to have bioactive potential (Boland, 2013; Henare, 2015; Meleleo et al., 2012). The fatty acid content in kiwi pulp is relatively low. However, 75% of its total fatty acids are polyunsaturated, mainly linoleic and α-linoleic acids, which are recognized as healthy lipids (Dias et al., 2020; Henare, 2015).

In terms of fiber content, the contribution of both soluble and insoluble fiber of the green kiwi (*A. deliciosa*) is higher than in other fruits such as oranges and apples. Fiber is susceptible of fermentation and provide benefits through the production of short chain fatty acids. In addition, it significantly slows down the mixing and diffusion of glucose at intestinal level (Mishra, Edwards, Hedderley, Podd, & Monro, 2017). Fiber is also known for its prebiotic properties, since it stimulates the intestinal motility, increases satiety, and contributes to better digestive and intestinal microbiota health (Wojdyło et al., 2017).

Regarding the micronutrients, kiwi is considered a rich source of vitamin C. For instance, the intake of 100 g (1–2 pieces of fruit) of *A. chinensis* covers approximately 260% of the daily recommendations for vitamin C in adults (López-Sobaler et al., 2016). In addition, several studies found that the consumption of four kiwis a day for four weeks increased plasma concentrations of vitamin C, α-tocopherol, and lutein/zeaxanthin, as well as folate concentrations in erythrocytes. The systemic effects of this intake, mainly associated with their high bioavailability, accounted for the reduction of complications and the duration of respiratory infections and plasma lipid peroxidation (Brevik et al., 2011; Hunter et al., 2012; Stonehouse et al., 2013). On the other hand, it is worth noting the high content of vitamin E in kiwi, comparable to avocado (Stonehouse et al., 2013). Its main form is as α-tocopherol which is mostly present in the pulp, while in the skin is usually found the δ-tocomonoenol, both of which are highly bioavailable (Fiorentino et al., 2009; Hunter et al., 2012). In the same way, other forms such as β or γ-tocopherol or γ-tocotrienol (Fig. 1) may appear in the pulp in smaller quantities. Furthermore, kiwis are an excellent source of folic acid (vitamin B9), managing to provide up to 15% of the recommended daily intake (Richardson et al., 2018).

Among the broad variability of biomolecules contained in kiwis, the phenolic compounds are the most relevant in terms of concentration and distribution. They are present in the different botanical parts of the plant, however, their content decreases during the process of fruit ripening. Their main representatives in kiwis are phenols and flavonoids, characterized by their antitumor and antioxidant properties. (X. He et al., 2019). Numerous studies have chemically characterized and quantified their presence in kiwi. For example, a recent study on *A. arguta* identified and quantified by liquid chromatography coupled to mass spectrometry (LC-MS) and photodiode array (LC-PDA) 24 phenolic compounds, 18 of which were flavonoids (flavonoids, polymeric flavan-3-ols and anthocyanin) and the remaining 6, phenolic acids. The total concentration of phenolic compounds ranged from 2400 to 6700 mg/100 g of dry weight (dw). Of the flavonoids, flavan-3-ols represented between 96% and 99% of the total polyphenolic compounds, followed by flavanols (1–4%) and finally anthocyanins (0–0.8%) (Wojdyło et al., 2017). Flavanols were derived mainly from quercetin and kaempferol, while flavan-3-ols were derived from catechin and epicatechin, and among the phenolic acids were: caffeic and *p*-coumaric acid, as well as derivatives of chlorogenic and quinic acid (Wojdyło et al., 2017). Other authors have underlined the additional presence of ferulic, protocatechuic, vanillic acid and derivatives of coumaric and hydroxycinnamic acid (Henare, 2015). The chemical structures of these and other bioactive molecules are summarized in Fig. 2. Another study compared the content of phenolic compounds in different varieties of *A. arguta* and *A. deliciosa* cultivar "Hayward" using spectrophotometric measurements. The values obtained were 19.7–28.6 mg gallic acid equivalents (GAE) per 100 g fresh weight (fw) and 19.4 mg GAE/100 g fw for *A. arguta* and *A. deliciosa* pulp, respectively. On the other hand, some authors estimated by spectrophotometry the content of bioactive compounds in different varieties of kiwi and using different solvents. The content of polyphenols, flavonoids, flavonols and tannins per g of dw was 0.3–16.3 mg GAE, 0.3–4.3 mg of catechin equivalents (EC), 3.1–42.9 mg of EC and 0.5–3 mg of EC, respectively (Park et al., 2014). The wide quantitative ranges observed for the total content of phenolic compounds in these studies are probably due to the variability of the experimental protocols. The main differences found between the methods include the use of different varieties of kiwi, the use of dry or fresh material, the solvent selected for the extraction and the quantification method. Besides, the antioxidant capacities of kiwi have been directly related to polyphenols, while the flavonoids quercetin, kaempferol, epicatechin, and hesperidin, were described to possess antibacterial and antiviral activities (Y. M. Kim et al., 2020). Therefore, kiwi is a valuable source of phenolic compounds, with potential for application in the food industry and for health prevention (Baranowska-Wójcik & Szwajgier, 2019).

On the other hand, it is important to highlight the volatile compounds as they provide the characteristic aroma of kiwi. This profile is the result of combining a minimum of 26 molecules such as acetaldehyde, benzaldehyde, decanal, hexanal, octanal, nonanal, hex-E2-enal, hexanol, 1,8-cineole, tanol, methyl butanoate and ethyl octanoate, among others (X. He et al., 2019; Talens, Escriche, Martínez-Navarrete, & Chiralt, 2003). In general, the volatile compounds from the kiwifruit can be grouped into the following classes: terpenes, benzenoids, esters, aldehydes, ketones, alcohols, acids, hydrocarbons, furans, and sulfur compounds (Matich et al., 2003). One study that identified up to 80 volatile compounds in kiwi fruits extracts found that monoterpenes (such as, menthol) can get masked by esters such as ethyl butanoate, hexanoate, 2-methylbutanoate and 2-methylpropanoate, and by the aldehydes hexanal and hex-E2-enal (Matich et al., 2003).

Additionally, kiwi contains different pigments such as chlorophylls, carotenoids, and anthocyanins (Latocha, 2017; Nishiyama, 2007). The yellow color of *A. chinensis* is due to the presence of carotenoids, while the green kiwi (*A. deliciosa*) has higher levels of chlorophylls although the content in *A. arguta* can be double (Nishiyama, Fukuda, & Oota, 2005). Carotenoids present in kiwi include violaxanthin, neoxanthin, lutein, and β-carotene. In the case of red-fleshed kiwis, they also present: 9′-*cis*-neoxanthin, anthraxanthin, zeaxanthin and β-cryptoxanthin (X. He et al., 2019). The content of lutein ranges between 0.1 and 1.0 mg/100 g of fw depending on the species, *A. deliciosa* and *A. arguta* usually present higher values than *A. chinensis*. Similarly, the concentration of

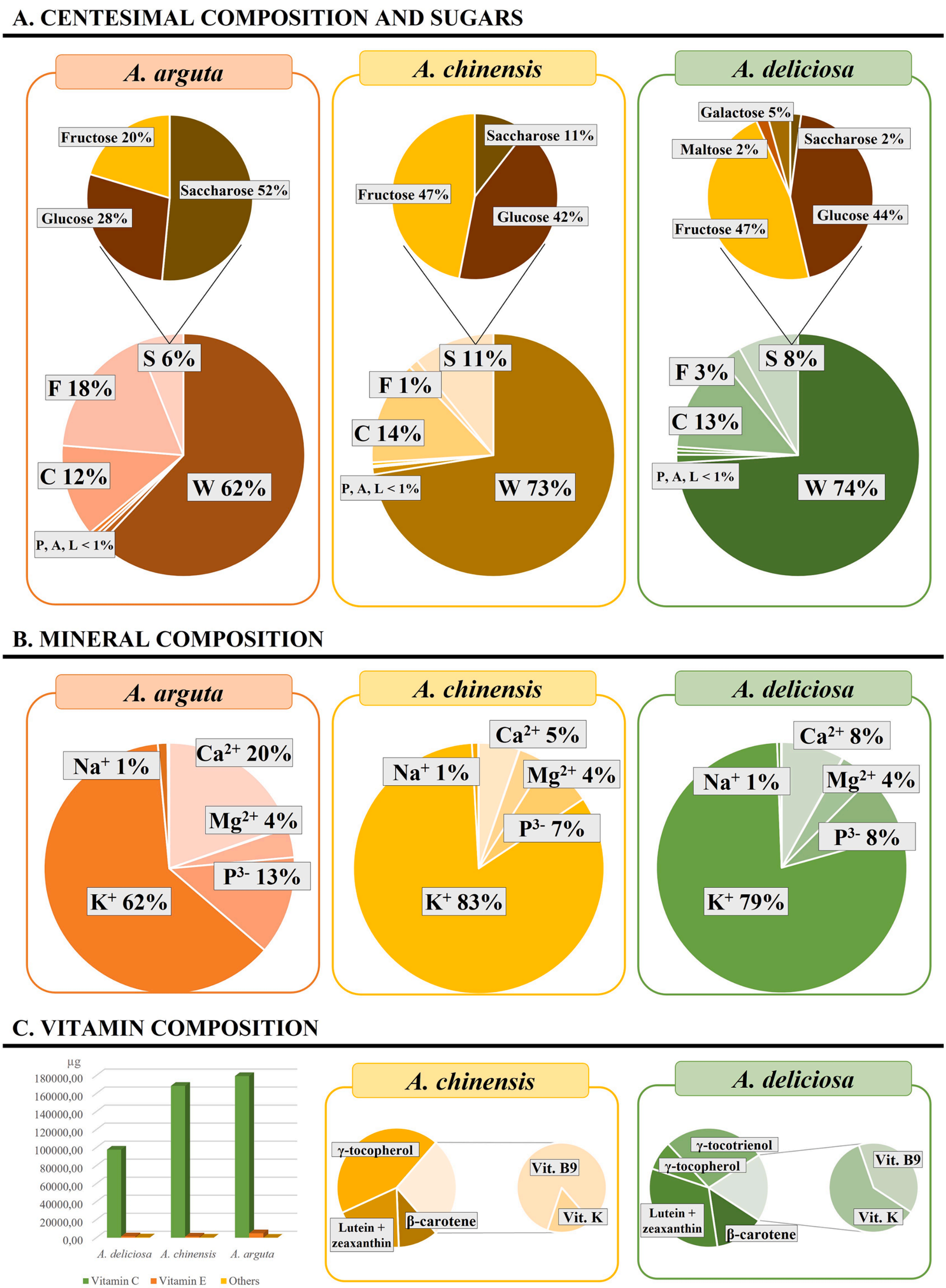

Fig. 1. Nutritional composition of the three varieties of greatest commercial interest (Latocha, 2017; Pinto et al., 2020; Wojdyło et al., 2017). *Abbreviations:* S: Sugars; F: Fiber; C: Carbohydrates; W: Water, P: Proteins, A: Ashes; L: Lipids. * *A. arguta* vitamins only entail β-carotene besides vitamin C and E (not represented).

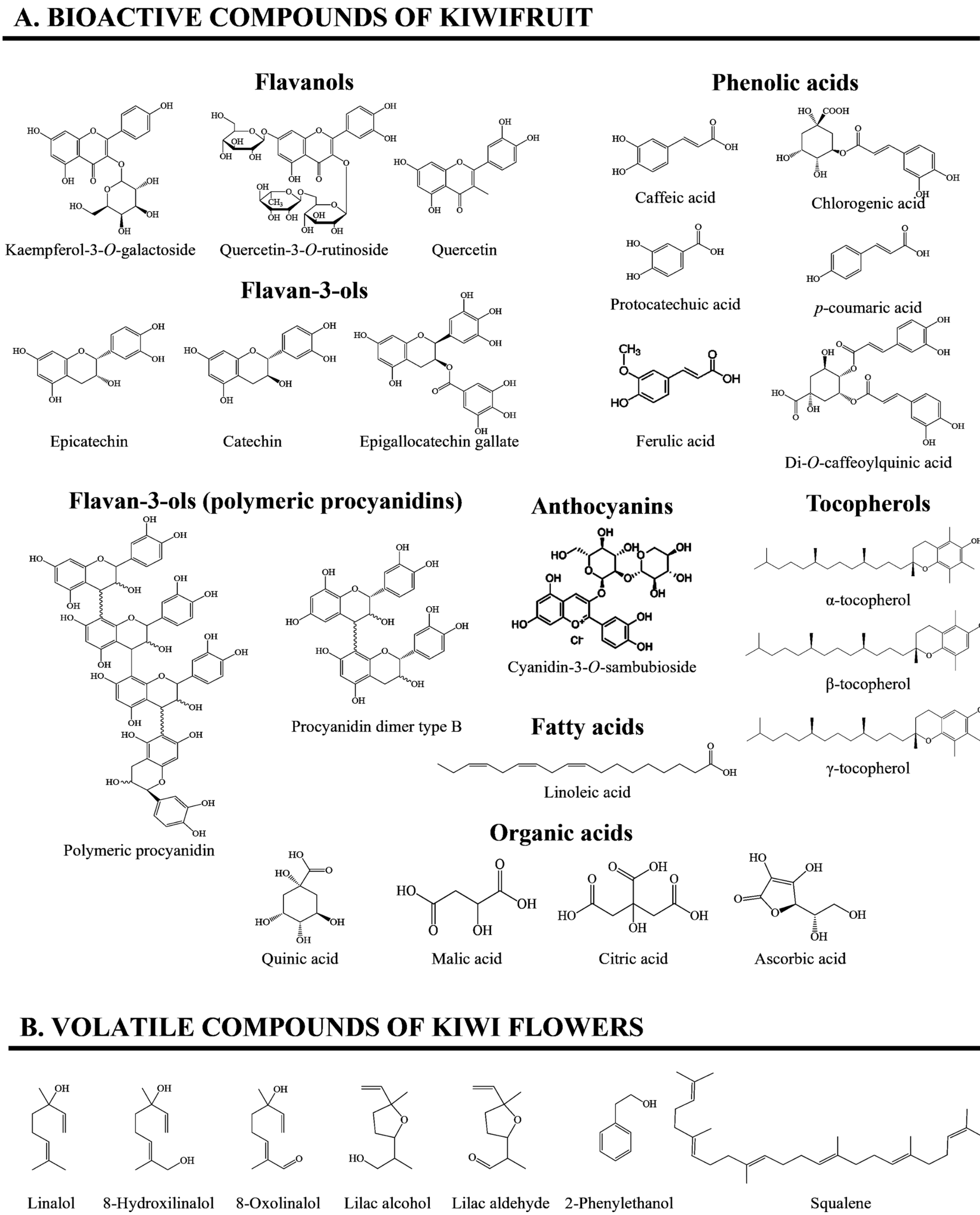

Fig. 2. Molecular structures of the main bioactive compounds present in kiwi by-products (part A) and the structures of volatile compounds usually present in kiwifruit flowers (Part B).

β-carotene varies among the most popular varieties: *A arguta* "Ananasnaya" shows valued of 0.285 mg/100 g of fw which triplicated the content in *A. deliciosa* "Hayward" and *A. chinensis* "Hort16A" (0.09 and 0.07 mg/100 g of fw, respectively) (Nishiyama et al., 2005). Regarding, anthocyanins, most of them derive from cyanidin, such as cyanidin-3-*O*-sambubioside in *A. arguta*, cyanidin 3-*O*-xyl-(1–2)-galactoside in *A. chinensis* or cyanidin 3-*O*-galactoside and cyanidin 3-*O*-glucoside in *A. deliciosa* (Nishiyama, 2007; Wojdyło et al., 2017). These pigments, both carotenoids and anthocyanins, are frequently used as colorants in food products and vegetable dyes in the food industry (Baranowska-Wójcik & Szwajgier, 2019).

Therefore, kiwi, and specifically, the pulp has a wide range of bioactive molecules like carotenoids such as lutein and β-carotene, anthocyanins, chlorophyll, phenolic compounds, flavonoids and even volatile substances (Fig. 2) (Leontowicz et al., 2016). These bioactive compounds confer different properties such as antioxidant, anti-inflammatory, anti-tumor, immunoregulatory, lipid-lowering, anticholinergic and cardiovascular protection (X. He et al., 2019; Wojdyło et al., 2017), especially relevant for the prevention and treatment of pathologies associated with cancer, oxidative stress and aging (X. He et al., 2019).

2.2. Skin

The skin of kiwi varieties such as Bruno and Monty provide an energy intake of 228–249 Kcal/100 g of dw. Regarding macronutrients, it has a percentage of carbohydrates of 49–54%, 0.6–2.5% of lipids and 3.6–4.6% of proteins (in dw) (Soquetta et al., 2016). In the case of the variety *A. deliciosa*, it may contain a greater amount of macronutrients, with a higher content in dw of carbohydrates (77%) and proteins (13%) (Salama et al., 2018).

In general, the skin of all kiwi species has a higher biological activity compared to the pulp (Latocha et al., 2015; M. A. Skinner, Bentley-Hewitt, Rosendale, Naoko, & Pernthaner, 2013). This may be due to the higher content of some molecules such as flavonoids (Baranowska-Wójcik & Szwajgier, 2019). Some authors claim that it is a good source of phenolic compounds with reported quantifications of 13 mg GAE/g of dw in *A. deliciosa* (Bernardes et al., 2011; Dias et al., 2020; Wojdyło et al., 2017; Yang et al., 2013). However, as observed for data relative to pulp, huge differences were found among published studies, such as the reported levels of phenolic compounds in the skin of *A. arguta* and *A. deliciosa* was around 2.65 mg GAE/g fw and 0.91 mg GAE/g fw, respectively (Chai et al., 2014). Regarding the chemical composition of kiwi skin, the organic acids, quinic, malic or citric stand out and epicatechin is the main polyphenolic compound in both green (163 mg/g) and red kiwi (110 mg/g) while the main pigment class is anthocyanins, with proanthocyanidins as major representatives (Latocha, 2017). Kiwifruit skin is also rich in vitamin E, with α-tocopherol as the most abundant form (2.4 mg/100 g fw) although it presents the three isoforms (α-, γ- and δ-tocopherol) together with the δ-tocomonoenol (Dias et al., 2020; Leontowicz et al., 2016; Nishiyama et al., 2005). Kiwifruit provides higher amounts of tocopherols than grapes and plums (Latocha, 2017), so it would be convenient to explore its skin as an ingredient to obtain extracts in the food industry due to its healthy properties (Dias et al., 2020). Additionally, the high content of flavonoids in the skin has been described to exert more powerful antioxidant, antibacterial and anticancer activities than the pulp (Alim et al., 2019) and anthocyanins are capable of inhibiting the activity of tyrosinases.

2.3. Seeds

The nutritional composition of the seeds has not been so deeply studied. Nevertheless, they are described to possess 14% of proteins, and 35% of lipids in dw (Deng et al., 2018), mostly unsaturated fatty acids, mainly linoleic acid (X. He et al., 2019; Latocha, 2017). However, the oxidative instability of fatty acids, requires careful extraction procedures and proper packaging and storage (Deng et al., 2016). In addition, the seeds also contain γ-tocopherol, γ-tocotrienol and ϱ-tocotrienol (Richardson et al., 2018). The content of total phenolic compounds in kiwi seeds of various varieties is around 2.0 GAE g/100 g for the variety *A. arguta* (Deng et al., 2018). The LC-UV quantification of phenolic compounds in seeds of the Hayward variety provided values of 329 mg/g, highlighting the presence of catechin (45 mg/g), *p*-coumaric acid (53 mg/g) and *p*-hydroxybenzoic acid (63 mg/g) (Wang et al., 2018).

The high content of vegetable protein of kiwi seeds converts them into a very interesting substitute for soy protein. Kiwi seed proteins have better digestibility and a better proportion of essential amino acids than that recommended by FAO and WHO (Yang et al., 2014). Therefore, kiwi seeds may become a potential matrix for food industry as source of edible proteins instead of a waste. Regarding its lipid composition, vegetable oils are described to provide various health benefits due to their antioxidant, anti-diabetic, or anti-obesity properties. These fatty acids may intervene in liver functions, inflammatory processes or lipid metabolism, among others (Fotschki, Jurgoński, Juśkiewicz, & Zduńczyk, 2015; Mohammed A Hussein, 2014; Nie et al., 2020; Qu, Liu, Zhang, Tuo, et al., 2019). Indeed, kiwi seed oil exhibits strong anti-inflammatory activities by suppressing the secretion of pro-inflammatory cytokines such as interleukin-1β (IL-1β) and tumor necrosis factor-α (TNF-α) (Deng et al., 2016; Richardson et al., 2018). A recent study found that supplementing the diet with kiwi seed oil for 12 weeks decreased lipid accumulation, body weight, blood glucose, and expression of inflammatory cytokines in a mouse animal model (Qu, Liu, Zhang, Tuo, et al., 2019). Besides, these activities may be reinforced by the presence of catechin, *p*-coumaric acid and *p*-hydroxybenzoic acid which also exhibit strong antioxidant and anticancer activities, while caffeic acid, and ferulic acid have potential therapeutic effects in diabetes and hyperlipidemia (Wang et al., 2018). Given these attributes, and given that kiwi seeds can be considered agro-industrial waste (Deng et al., 2016), they are promising matrixes as a source of bioactive compounds with antioxidant capacities (Deng et al., 2014) that might be even used as dietary supplement (Deng et al., 2018).

3. Agricultural kiwi wastes

As exposed before, kiwi cultivation accounted for ~ 270 × 103 ha around the world in 2019 and implied a global production of kiwi of ~ 4.5 × 10^6 tons (FAO, 2020). The exploitation of such a huge production of kiwi as a fruit species entails the generation of several residues not intended for consumption or further uses. Some studies have determined that the annual biomass from orchard tree pruning may reach 3 Mg of dw per hectare (Manzone, Gioelli, & Balsari, 2017). Generally, they mostly end up being incinerated or used as a substrate for compost production. However, they are plant fractions rich in bioactive compounds that can be recovered in the same way as from the residues derived from fruit processing. Their reutilization would have a direct impact on kiwi producers since they would represent a sustainable and natural source of biomolecules that may report economic benefits and reduce their environmental impact. These residues are leaves, stems and to a lesser extent, flowers.

3.1. Leaves

All cultivated species of kiwi are deciduous hence a remarkable biomass of leaves can be naturally generated. To optimize and maximize fruit production, it is necessary to carry out pruning tasks on the plants, both in summer and winter, and between 18 and 40 branches per plant and pruning can be obtained (Pinto et al., 2020; Salinero & Sainz, 2005). In this way, both natural and mechanical removal of leaves annually sum considerable amounts of biomass that nowadays has not defined applications. Contrarily, kiwi leaves have a long history of use in traditional Chinese medicine for anti-inflammatory purposes (Latocha, 2017), and thus for the control of different inflammatory-based diseases such as arthritis, bronchitis and gastritis. In China and South Korea, they are also consumed as food (Pinto et al., 2020). The concentration of bioactive compounds in leaves has been observed to vary depending on the solvent used for the extraction (Cyboran, Oszmiański, & Kleszczyńska, 2014). Nevertheless, the average concentration of phenolic compounds in leaves is relatively high, especially in the case of acids, with values around 200 mg/g of leaf (Pinto et al., 2020). Indeed, among the phenolic compounds found in kiwi leaves, the neochlorogenic acid, chlorogenic acid, cryptochlorogenic acid, caffeoylquinic acid, glycosylated quercetin and kaempferol derivatives, catechin and type B procyanidin dimers are the most significant (Almeida et al., 2018; Cyboran et al., 2014).

In relation to their biological properties, a recent work conducted a screening of leaf metabolites and studied their anti-inflammatory activity through evaluation of the production of nitic oxide in RAW 264.7 macrophages induced by lipopolysaccharides (LPS). The study determined that compounds derived from caffeic acid, like the identified caffeoyltreonic acid and salvanic acids, were able of counteracting the inflammatory effect induced by LPS (G. Kim, Lee, & Auh, 2019). Another study analyzed the phenolic acids and flavonoids composition of *A. arguta* leaves which displayed a higher content of total phenolic compounds (TPC) than that previously reported for the fruit. The high TPC demonstrated a strong antioxidant capacity *in vitro* with a half inhibitory concentration (IC_{50}) of 270 ± 70 µg/mL for the antioxidant assay DPPH that measures its potential to eliminate reactive species (Marangi et al., 2018). However, other authors have indicated even lower IC_{50} values (54 µg/mL) for DPPH assays and an associated antimicrobial capacity against *Staphylococcus aureus* when using leave extracts of 50 mg/mL (Almeida et al., 2018). Additionally, cytotoxic studies of these extracts on colorectal cancer cell lines suggested that it may have a cytostatic effect on these tumor cells (Henriques, Luis, Pacheco, Helena, & Luísa, 2018). While, regarding, catechins and their dimers, they were described to induce changes in the average tonicity of red blood cells and make them more resistant (Pinto et al., 2020).

3.2. Flowers

Kiwi flowers are not categorized as *a priori* residue since their fertilization and correct development lead to the production of the fruit and influence its quality. However, to maintain optimum production, as mentioned, it is necessary to carry out pruning and maintenance tasks before and after flowering, called "clearing" (Salinero & Sainz, 2005). The need for these pruning procedures on the plant arises from the formation of excessive or poorly formed buds that will not give rise to quality fruits. Although the mass of flowers resulting as a residue would not reach high amounts, its richness and high concentration of volatile and phenolic compounds; coupled with the ease of extraction thereof from this type of matrix, make flowers an important source of bioactive compounds to be explored (Trinh, Choi, & Bae, 2018).

Kiwifruit flowers are appreciated for representing an interesting source of volatile compounds (Fig. 2). Above all, they have been identified derivatives of linalool, including aldehydes (12a-d) and alcohols (13a-d), 2,6 -dimethyl-6-hydroxyocta-2,7-dienal (8), 8-hydroxylinalol (9), sesquiterpenes and benzene compounds, presumably phenylalanine and tyrosine metabolites (Matich et al., 2003). In addition, it has been pointed out that the flowers present (3E, 6E)-α-farnesene, pentadecane, (+) (-) germacrene, heptadecane, (8Z)-heptadecene, 2-phenylethane, (3Z, 6Z, 9Z)-heptadecatriene and nonadecane, in this order of abundance (X. He et al., 2019). The diversity of these compounds make them very usefulness ingredients for their use as flavoring agents in food matrixes or alcoholic beverages where they are aimed to improve the organoleptic properties of the final products (Pinto et al., 2020).

3.3. Stems and roots

The pruning required in summer and winter seasons on kiwi plants can give rise to an important mass of stems and branches. This woody stems and branches of the kiwi plant can difficult the extraction processes due to the presence of lignin. However, they can be used as substrate for the production of bioethanol or as a natural source of some bioactive compounds they contain at high concentrations (Manzone et al., 2017; Picchi, Lombardini, Pari, & Spinelli, 2018). The composition of phenolic compounds is similar to that of leaves, with the exception of differences in pigment levels (Marangi et al., 2018) therefore they are contemplated as a rich source of phenolic compounds. In fact, it has been shown that extracts obtained from kiwi stems can inhibit the activity of the α-glucosidase enzyme, reducing elevated postprandial blood glucose levels in diabetics (Lee et al., 2014; Wojdyło et al., 2017). Its anti-inflammatory properties have also been studied in RAW 264.7 macrophages stimulated by LPS. Results showed that methanolic extracts of *A. arguta* branches (20 µg/mL) decreased the nitric oxide production by 40% by interfering along the nuclear factor (NF)-κB and mitogen-activated protein kinase (MAPK) pathways (H. Y. Kim, Hwang, & Park, 2014). Moreover, dietary fiber components that can be obtained from these lignocellulosic residues may be used in prebiotic formulations or functional foods together with other components and extracts obtained from kiwi (Blatchford et al., 2015).

On the other hand, roots also rich in bioactive compounds, results less accessible (Latocha, 2017). The chemical profile of roots of *A. chinensis* have been described to include the presence of triterpenoids, polysaccharides and phenolic compounds (X. He et al., 2019; Pinto et al., 2020). Regarding the composition of the essential oil extracted from *A. chinesis* roots, analyses have revealed that the main components are dodecane, octane, decane, paeonal, camphor, *n*-decanoic acid, 4-methyldodecane, undecane and linalool oxide (J. He et al., 2014; A. Yu, Tian, & Qu, 2009) although other authors have indicated that kiwi roots contain two coumarins: esculin and fraxin (Hirsch & Longeon, 2002; Pinto et al., 2020). The bioactive compounds of *A. chinensis* root extract have demonstrated anti-tumor and anti-inflammatory properties (X. He et al., 2019; Pinto et al., 2020). Similarly, triterpenoids found in kiwi roots, especially those with a carboxyl group, showed significant cytotoxicity ability against various types of tumor cell lines *in vitro*, especially in lung (Lv, Wang, Shen, & Wang, 2018), liver, colon and gastric cancer cells (X. He et al., 2019; Wei, Ma, Liu, Huang, & Liao, 2018).

4. Biological properties

4.1. Antioxidant activity

The high content of biomolecules presents in kiwi, such as vitamin C (ascorbic acid), vitamin E, phenolic compounds and carotenoids (lutein and zeaxanthin), are considered great antioxidant and anti-inflammatory compounds (Latocha, 2017; Leontowicz et al., 2016). They mainly exert their mechanism of action through the neutralization of reactive species, both oxygen and nitrogen. These free radicals are involved in developing oxidative damage associated to so many pathologies such as cardiovascular diseases or cancer (Latocha et al., 2015; Stonehouse et al., 2013). Therefore, these molecules may prevent oxidation prompting the enhancement of oxidative defenses by upregulating genes related to deoxyribonucleic acid (DNA) repair (Stonehouse et al., 2013). A summary of the biological properties exerted by kiwi extracts is displayed in Table 2.

The antioxidant capacities of natural extracts are usually determined in equivalents of the 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid, a strong antioxidant derived from vitamin E, commonly named Trolox. It can be measured by using different assays such as the ferric reducing antioxidant power (FRAP) based on metal ions, those using organic radical producers like 2,2′-azinobis(3-ethylbenzothiazoline-6-sulfonic acid) [ABTS] and 2,2-difenil-1-picrylhydrazyl [DPPH] (it

Table 1
Phenolic compounds of *Actinidia* sp. fruits.

Composition	Chemical structure	Residue	Ref.
Flavanols	Kaempferol-3-*O*-galactoside	Pulp	(Wojdyło et al., 2017)
		Leaves	(Cyboran et al., 2014; Pinto et al., 2020)
	Quercetin-3-*O*-rutinoside	Pulp	(Wojdyło et al., 2017)
	Quercetin	Skin	(Dias et al., 2020)
Flavan-3-ols	Epicatechin	Skin	(Dias et al., 2020)
		Leaves	(Cyboran et al., 2014; Pinto et al., 2020)
	Catechin	Skin	(Alim et al., 2019)
		Leaves	(Cyboran et al., 2014; Pinto et al., 2020)
		Roots	(Latocha, 2017; Lee et al., 2014; Pinto et al., 2020)
	Epigallocatechin gallate	Pulp	(Leontowicz et al., 2016)
	Polymeric procyanidins	Pulp	(Wojdyło et al., 2017)
	Procyanidin dimer type B	Leaves	(Cyboran et al., 2014; Pinto et al., 2020)
Phenolic acids	Caffeic acid	Pulp	(Wojdyło et al., 2017)
		Seeds	(Deng et al., 2016)
	Chlorogenic acid	Pulp	(Leontowicz et al., 2016; Wojdyło et al., 2017)
		Leaves	(Cyboran et al., 2014; Pinto et al., 2020)
	Protocatechuic acid	Seeds	(Deng et al., 2016)
	p-coumaric acid	Seeds	(Deng et al., 2016)
		Leaves	(Cyboran et al., 2014; Pinto et al., 2020)
	Ferulic acid	Seeds	(Deng et al., 2016)
	Di-*O*-caffeoylquinic acid	Pulp	(Leontowicz et al., 2016)
Anthocyanins	Cyanidin-3-*O*-sambubioside	Pulp	(Wojdyło et al., 2017)
Tocopherols	α-tocopherol	Skin	(Dias et al., 2020)
	β-tocopherol	Skin	(Dias et al., 2020)
	γ-tocopherol	Skin	(Dias et al., 2020)
		Seeds	(Deng et al., 2016)
Organic acids	Quinic acid	Skin, Pulp	(Dias et al., 2020; Wojdyło et al., 2017)
	Malic acid	Skin	(Dias et al., 2020)
	Citric acid	Skin	(Dias et al., 2020)
	Ascorbic acid	Skin	(Dias et al., 2020)

is assessed the ability of the antioxidants to scavenge the radicals), and the oxygen radical absorbance capacity (ORAC). The antioxidant capacities of the bagasse of kiwi bagasse were estimated with different spectrophotometric assays as follows: 0.71 mmol Trolox/100 g measured by FRAP; 0.57 mmol Trolox/100 g by ABTS; and 1.36 mmol Trolox/100 g by ORAC (Table 2). Besides, the content of hydrophilic molecules was positively related with data obtained from FRAP and ABTS tests, specifically, in the FRAP test, it was correlated with the amount of ascorbic acid. However, this study does not exclude the hypothesis of the synergy between hydrophilic and lipophilic molecules for the antioxidant capacity (D'Evoli et al., 2015). In another work based on kiwi meat decoctions, it was demonstrated to have antioxidant activity and a good capacity for neutralizing reactive oxygen and nitrogen species such as hypochlorous acid and nitric oxide (Margarida et al., 2019). In another study, the consumption of green kiwifruit (*A. deliciosa*) in combination with other foods was associated with a higher postprandial plasma antioxidant capacity. Thus, the consumption of *A. deliciosa* may prevent the postprandial oxidative stress (Prior et al., 2007).

Regarding to the antioxidant capacity of kiwi skins, ethanolic extracts were established as good antioxidants after their quantification by DPPH (107 μg/mL) and ABTS (258 μg/mL) (Salama et al., 2018). Another study compared the composition of flours made from kiwi skins at different ripening stages in terms of phenolic compounds and antioxidant capacity. The flour obtained from the variety Bruno presented higher levels of phenolic compounds (1.3 g GAE/100 g of flour) against Monty (around 1 g GAE/100 g of flour) which probably provided a stronger antioxidant capacity by DPPH. However, the Monty variety flour presented higher antioxidant capacity by FRAP (from 48 to 414 μmol of TEAC/100 g) and higher levels of vitamin C (189 mg/100 g), flavonoids (486 mg/100 g), and pigments (carotenoids 247 μg/100 g) (Soquetta et al., 2016). In this sense, the antioxidant capacity of kiwi skins was reported to be greater than kiwi pulp when assessed by two tests, inhibition of the formation of reactive substances of thiobarbituric acid reactive species (TBARS) and inhibition of oxidative hemolysis (OxHLIA) (Dias et al., 2020).

Regarding the antioxidant capacity of kiwi seeds, diverse studies have analyzed their potential. When quantified by spectrophotometric techniques, levels of 107 mg Trolox/kg were reported by FRAP, 2 mg of Trolox/kg by ORAC, and an IC_{50} of 35 mg/mL by DPPH assay. The difference in these values indicates the importance of using diverse methods to analyze the antioxidant capacity of kiwi extracts, due to the affinity of each method with hydrophilic or lipophilic molecules. Likewise, the antioxidant capacity of kiwi leaf extract was also determined. It was concluded that it can protect the cell membrane against free radicals induced by physicochemical agents, Thus, this extract may be a potential food additive that could inhibit lipid oxidation in food products exposed to ultraviolet B (UVB) radiation (Cyboran et al., 2014).

Despite polyphenols are the main agents of many of the bioactivities, their biological functions depend on their bioavailability. Hence, *in vivo* studies to analyze how polyphenols from different botanical parts of the kiwi plant get released, absorbed, distributed, metabolized and eliminated are necessary (Pinto et al., 2020). Also, further studies are recommended for the isolation of bioactive components and biological test methods.

4.2. Antitumor activity

Cancer is a complex disease in which various factors intervene and whose treatment is arduous. Several studies have focused on preventing the appearance of this pathology through a healthy lifestyle, as well as on the preventive and/or palliative effects of diet in combination with other therapies (Tajan & Vousden, 2020). In this sense, a study estimated that if half of the American population increased their consumption of fruits and vegetables, around 20,000 cases of cancer would be avoided. The beneficial effect of consuming fruits is due to their composition rich in micronutrients and bioactive compounds (Reiss, Johnston, Tucker, DeSesso, & Keen, 2012). Some authors state that the components responsible for antimutagenicity are water-soluble and thermolabile phenolic compounds (Latocha et al., 2015).

In this sense, kiwi might be considered as a preventive antitumor agent, acting in two different ways. On the one hand, it can contribute to the protection or reduction of DNA damage and mutagenesis processes, constituting chemoprevention strategies (Hunter, Skinner, & Ferguson, 2016) since kiwi ingestion accompanied by a balanced diet may provide protection against DNA damage (S. J. M. Skinner, Hunter, Cho, & Skinner, 2013). Such is the case of kiwi ethanolic extracts, which prevented the *in vitro* mutagenic activity of *N*-nitrosamines (Hunter et al., 2016; Ikken et al., 1999). In fact, components of *A. arguta* have been proposed as attractive candidates for their potential use as chemopreventive agents (Nishimura et al., 2016). Likewise, diverse parts of *A. chinensis* are widely used as pharmaceutical raw materials in medicine for the prevention and treatment of tumors (X. He et al., 2019). On the other hand, the possible role of kiwi in cell proliferation and tumor formation has also been studied (Hunter et al., 2016). Some *in vitro* investigations confirmed the inhibitory effect of different extracts of *A. arguta, A. chinensis* and *A. kolomikta* in some human cancer cell lines such as the hepatocellular (HepG2) or the colon carcinoma (HT29) (Zuo, Wang, Fan, Tian, & Liu, 2012) (Table 2). Specifically, an *A. arguta* polysaccharide (AAP-3b) was able to inhibit the proliferation of human

Table 2
Biological properties of different vegetal tissues of diverse *Actinidia* species.

Species	Tissue	Compound	Assay	Activity	Ref.
Antioxidant activity					
A. arguta	L	Polyphs	*In vitro* assay (erythrocytes)	Cellular membrane protection against UVB-, UVC- and AAPH-free radicals	(Cyboran et al., 2014)
A. chinensis,A. deliciosa,A. arguta	Sd	Phs and FA	FRAPORACDDPPH	3.3–107.3 mg Trolox/kg1.3–2.0 mM Trolox/ kg26–35 mg/mL (IC_{50})	(Deng et al., 2018)
A. deliciosa	P	VitC, polyphs, carotenoidsand tocols	FRAP, ABTS, ORAC	5–20 μmol Trolox/g	(D'Evoli et al., 2015)
A. deliciosa	F	Polyphs	ORAC	12.5 mmol Trolox	(Prior et al., 2007)
*A. deliciosa*var. Hayward, *Actinidia* spp.	P, Sd	VitC, polyphs,and organic acids	TBARSOxHLIA	76–406 μg/mL182–545 μg/mL	(Dias et al., 2020)
*A. deliciosa*var. Monty	Sk	Polyphs	DPPH ABTS	107 ± 9 μg/mL 258 ± 1 μg/mL	(Salama et al., 2018)
	Sk (flour)	VitC, flavonoids, carotenoids	FRAP	0.5–4.1 μmol of Trolox/g	(Soquetta et al., 2016)
Antitumor activity					
A. arguta	P	AAP-3b	HepG2	Inhibition of cell proliferation (GI_{50} = 76–193 μg/ mL, 24–72 h)	(X.-L. Yu et al., 2015)
A. arguta,A. chinensis,A. kolomikta	P, L	VitC, phs, and flavonoids	HepG2 and HT-29	Inhibition of cell proliferation (GI_{50} = 30–175 mg/ mL)	(Zuo et al., 2012)
A. chinensis	P	ND	*In vitro* assays	Prevented the mutagenic activity of *N*-nitrosamines	(Ikken et al., 1999)
A. chinensis	P, Sk	Polyphs and flavonoids	HepG2	Inhibition of cell proliferation (IC_{50} = 170 and 291 μg/mL for P and Sk)	(Alim et al., 2019)
A. deliciosa	P, Sk	VitC, polyphs, tocopherols, and organic acids	*In vitro* assays	Cytotoxic activity for MCF-7, NCI-H460, HeLa and HepG2	(Dias et al., 2020)
Anti-inflammatory activity					
A. arguta	P	Anthocyanins	A549 cell line	Inhibited secretion and activation of chemokines and NF-κB	(Peng et al., 2020)
A. chinensis	Sd	Phenolic acids	LPS-RAW 264.7	Decreased secretion of inflammatory cytokines IL-1β and TNF-α	(Deng et al., 2016)
A. chinensis	Sd oil	Phs and FA	C57BL/6 mice	Decreased body weight, lipid accumulation, blood glucose, and inflammatory cytokines	(Qu, Liu, Zhang, Tuo, et al., 2019)
A. chinensis,A. deliciosa	F	ND	BALB/c mice	Enhancement of immune system, modulation of innate and acquired immune cells	(Shu et al., 2008)
Antimicrobial activity					
A. arguta	L	Flavonoids and phenolic acids	–	Antimicrobial effect against *S. aureus*	(Almeida et al., 2018)
A. chinensis	Sk, P, Sd, St	ND	MIC	Inhibition of *S. aureus* and *S. pyogenes* (8–4 μg/mL) // *E. faecalis*, *S. typhi*, *P. mirabilis*, *P. aeruginosa*, *K. pneumoniae*, *E. coli,* (16–128 μg/mL)	(X. He et al., 2019)
A. chinensis	P, Sk	Polyphs and flavonoids	MIC	Inhibition against *S. pyogenes* and *P. aeruginosa* (1–8 μg/mL)	(Alim et al., 2019)
Digestion enhancement and gastrointestinal health					
A. chinensis	P, Sk	Polyphs	*In vivo* assays	Improved gut microbiota in Sprague Dawley rats	(Alim et al., 2020)
A. deliciosa Planch	P	Protease	Protease activity	Enzymatic activity 28.8 U/g	(Sun et al., 2016)
*A. deliciosa*var. Hayward	P	Protease	Digestibility	*In vitro* digestion of several dietary proteins	(Kaur et al., 2010)
A. deliciosa var. Hayward, *A. chinensis* var. Hort16A	P	Actinidin	*In vivo* assay	Improvement of digestion and rate of gastric emptying of meat proteins	(Montoya et al., 2014)
A. deliciosa	F	Polyphs	*In vitro* assays	Postprandial oxidative stress	(Prior et al., 2007)
*A. deliciosa*var. Hayward	F	VitC, lutein,catechin, fiber	*In vivo* assays	Increased frequency of daily bowel movements in C57BL/6J mice	(Ansell et al., 2015)
*A. deliciosa*var. Hayward	FF	Short chain FA	*In vitro* assays	Increase of gastrointestinal defensins in HT29	(M. A. Skinner et al., 2013)
*A. deliciosa*var. Hayward, *A. chinensis*var. Hort16A	FF	ND	Gastrointestinal digestion, anaerobic fecal batch cultures	Increment of organic acids, *Bifidobacterium* spp., and *Bacteroides* spp.	(Blatchford et al., 2015)
Other biological properties					
A. arguta	St	Moisture, ash, lipids, proteins, phs	*In vitro* assays	Inhibition of α-glucosidase, reduced levels of post-prandial blood G in diabetics	(Lee et al., 2014)
A. arguta	P	Polyphs	*In vitro* assays	Inhibition of α-amilase (IC_{50} 4.1–4.4 mg/mL) and α-glucosidase (IC_{50} 0.2–1.0 mg/mL)	(Wojdyło et al., 2017)
A. chinensis,A. deliciosa	P	Dietary fiber	*In vitro* digestion	Slows down the rate of glucose diffusion	(Mishra & Monro, 2012)
A. deliciosa	F	ND	*In vivo* assay	Decrease of 9–10 mm Hg of blood pressure in male smokers	(Karlsen et al., 2013)
*A. deliciosa*var. Hayward	P	Carbohydrates (glucose, fructose)	*In vivo* assay	Improve glycemic response in humans	(Mishra et al., 2017)
*A. deliciosa*var. Planch	Sd oil	FA	*In vivo* assay	Lower weight gain, cholesterol, TAG and LDL in obese mice	(Qu, Liu, Zhang, Liu, et al., 2019)

Abbreviations: AAPH: 2,2′-azobis(2-amidinopropane) dihydrochloride, FA: fatty acids, FF: fermented fruit, F: fruit, G:glucose, GI_{50}: growth inhibition 50%, IC_{50}: inhibitory concentration 50%, IL: interleukin, L: leaves, LDL: low density lipids, MIC: minimum inhibitory concentration, ND: Not determined; NF-κB: nuclear factor kappa-beta, P: pulp, Phs: Phenols, Sd: seed, Sk: skin, St; stems, TAG: tryacylglycerides, TNF-α: tumor necrosis tumor α, UVB/C: Ultraviolet B or C, VitC: Vitamin C (ascorbic acid).

liver cell tumors *in vitro*, and appeared to be associated with growth disruption and cell death (X.-L. Yu, Liu, Liu, Tan, & Liu, 2015). Furthermore, extracts of the green kiwi peel were described to possess cytotoxic activity in four human tumor cell lines studied: MCF-7 (breast adenocarcinoma), NCI-H460 (non-small cell lung cancer), HeLa (cervical carcinoma) and HepG2. Furthermore, no extract shows hepatotoxicity against porcine liver cells (GI_{50} greater than 400 μg/mL) (Dias et al., 2020). In agreement, kiwi polyphenols inhibited the proliferation of HepG2 cells showing time and dose dependence, with IC_{50} values of 170 μg/mL and 291 μg/mL for skin and pulp polyphenols after 72 h of treatment time, respectively (Alim et al., 2019) (Table 2). Furthermore, the previously mentioned prebiotic effect could also contribute to the modulation of colon bacteria, helping to the reduction of mutagens production (Nishimura et al., 2016). In general, further *in vivo* studies on kiwi antitumor properties are required to fully understand their mechanism of action (X. He et al., 2019).

4.3. Anti-inflammatory activity

Inflammation is the body's natural response to the presence of invasive foreign agents; however, this process can be altered by different metabolic or autoimmune diseases (Grivennikov, Greten, & Karin, 2010). In the case of kiwi, for example, the anti-inflammatory activity of the *A. chinesis* variety has been tested in *in vivo* and *in vitro* models (X. He et al., 2019). At the cellular level, certain phenolic acids such as protocatechuic, *p*-hydroxybenzoic, *p*-coumaric, caffeic and ferulic acids, present in the oil of *A. chinensis* seeds, applied at 40 and 60 μg/mL for 12 h, decreased the secretion of the pro-inflammatory cytokines IL-1β and TNF-α in RAW 264.7 cells induced by LPS (Deng et al., 2016) (Table 2). Similarly, a recent study related the consumption of kiwi seed oil for 12 weeks with the decreasing of lipid accumulation, body weight, blood glucose, and expression of inflammatory cytokines in a mouse animal model (Qu, Liu, Zhang, Tuo, et al., 2019).

Regarding kiwi skin, some authors have demonstrated its strong anti-inflammatory capacity, suggesting it as a potential preventive or therapeutic natural ingredient in cosmetic, pharmaceutical or nutraceutical formulations (D'Eliseo et al., 2019). Indeed, extracts of *A. chinensis* suppressed the secretion of pro-inflammatory cytokines, including IL-6 and TNF-α which confer it potential as anti-inflammatory agent (Deng et al., 2016). Additionally, the *in vitro* treatment of human alveolar epithelial cells (A549) with the polyphenolic extract of different varieties of kiwi displayed the reduction of chemokine levels. This biomarker is responsible for recruiting eosinophils and promoting the release of toxic granules and oxygen free radicals, which cause inflammation of the mucosa and contribute to the early development of allergic asthma. The results showed that extracts rich in anthocyanins inhibited the secretion and activation of chemokines and the NF-κB, both related to inflammation processes (Peng et al., 2020). Finally, and given that the inflammatory function is highly related to the immunological one, it has been proven that the phenolic compounds of the kiwi cell wall, as well as its vitamins and minerals, are capable of promoting a healthy immune system (M. A. Skinner et al., 2013), in addition to positively modulating the function of innate and acquired immune cells in mice (Shu et al., 2008) (Table 2).

4.4. Antimicrobial activity

All kiwi extracts (skin, pulp, seeds and stems) have showed bactericidal capacity against different strains such as *Staphylococcus aureus*, *Streptococcus pyogenes*, *Enterococcus faecalis, Salmonella typhi, Proteus mirabilis*, *Pseudomonas aeruginosa* and *Escherichia coli* (Basile & Sorbo, 1997). For instance, a study has shown that kiwi skin and pulp extracts have inhibitory activity against *S. aureus* and *S. pyogenes* with MIC values of 8 and 4 μg/mL; and against *E. faecalis*, *S. typhi*, *P. mirabilis*, *P. aeruginosa*, *E. coli* and *K. pneumonia* with MIC values ranging from 16 to 128 μg/mL (X. He et al., 2019). Regarding kiwi seeds, they showed bactericidal capacity against *S. pyogenes* and *P. aeruginosa* with MIC values of between 1 and 8 μg/mL (Alim et al., 2019) (Table 2). In addition, alcoholic and hydroalcoholic extracts from kiwi leaves exhibited a powerful antimicrobial effect against *S. aureus*, which could be related to the presence of flavonoids and phenolic acids (Almeida et al., 2018). Accordingly, in other studies, kiwi fruit agricultural waste and industry by-products were subdivided to analyze them against eight strains of Gram positive and negative bacteria. Data allowed concluding that all extracts had activity against bacteria of both types, in addition to exhibiting antiviral and antifungal properties (Baranowska-Wójcik & Szwajgier, 2019; Basile & Sorbo, 1997).

4.5. Digestion enhancement and gastrointestinal health

Recent studies have focused on the protease activity of kiwi extracts since they exhibit higher protease activity (28.8 U/g) when compared, for example, with papaya extracts (23.1 U/g) (Sun, Zhang, Yan, & Jiang, 2016) (Table 2). One study claimed the influence that kiwi have in the *in vitro* digestion of several dietary proteins, such as calcium caseinate and beef muscle protein, while other proteins such as collagen, gluten, and gliadin are least affected (Kaur, Rutherfurd, Moughan, Drummond, & Boland, 2010). Likewise, another study carried out in pigs, in this case *in vivo*, showed that actinidin, a proteolytic enzyme present mainly in kiwi pulp, exerts a positive effect on the digestion of meat proteins (especially those of high molecular weight), increasing its catabolism in the early stages of digestion (Montoya et al., 2014).

Kiwi was also evaluated through other digestive processes. For instance, a study conducted with kiwi extract powder to treat intestinal ailments such as constipation, showed its laxative effect in constipated mice (Zhuang et al., 2019). When tested in humans, the consumption of kiwi increased the frequency of daily bowel movements (Ansell et al., 2015). This laxative function of kiwi has generally been attributed to the content of dietary fiber, mainly cellulose, pectin polysaccharides and hemicelluloses, as well as the presence of glucuronoxylans and xyloglucans, and the action of actinidin and indigestible oligosaccharides (Leontowicz et al., 2016; Richardson et al., 2018). In this sense, a flour made from kiwi skin was reported to contain fiber levels between 26% and 30% (Soquetta et al., 2016). Furthermore, the cell walls contained in kiwifruit can retain more water, increasing fecal volume and improving laxation (Hunter et al., 2012).

In addition, both intestinal health and immune function are strongly influenced by microbial colonization of the gastrointestinal tract. The ingestion of prebiotic components (dietary fiber) may prevent the colonization by pathogenic bacteria by stimulating the proliferation of beneficial bacteria. This may generate favorable changes in the microbial community of the human colon and its metabolites, and thus enhance the intestinal health tightly related with a systemic health improvement (Nishimura et al., 2016; Richardson et al., 2018). In this sense, an *in vitro* study argued that kiwi fermentation products increased the production of gastrointestinal defensins (M. A. Skinner et al., 2013) (Table 2). Along the same line, the prebiotic capacity of kiwi has been studied in anaerobic fermenters used as models of the digestive system. The impact of kiwi on digestion caused changes in the ecology and metabolism of beneficial bacteria in the colon *(Bifidobacterium* spp. and *Bacteroides* spp.), increased their abundance, as well as the production of organic acids (Blatchford et al., 2015). A recent study also confirmed that dietary supplementation with two kiwis (without and with skin) per day improved the gut microbiota in healthy rats, increasing the microbial diversity of beneficial bacteria and reducing harmful bacteria (Alim et al., 2020). Therefore, it can be concluded that kiwi is a powerful agent that contributes to intestinal and digestive health, as it has been proved by both *in vitro* and *in vivo* assays performed in different species and in humans.

4.6. Lipid-lowering and antidiabetic activities

In general, and as previously mentioned, the content of vitamin C, carotenoids and phenolic compounds in kiwi provides a protective effect to consumers against cardiovascular diseases, which are highly affected by factors such as diet or physical activity (Gammon et al., 2014). For example, in a study conducted with male smokers, subjects who added three kiwis a day to their diet (balanced and supplemented with physical exercise), experienced a decrease of 10 and 9 mm Hg in systolic and diastolic blood pressure, respectively, being more pronounced in those with hypertension (Karlsen et al., 2013). Consumption of kiwi seed oil has also been shown to reduce weight gain, inguinal fat tissue, and accumulation of total cholesterol, triacylglycerides (TAG), and low-density lipoprotein (LDL) in an experimental model of mice with high-fat diet (Qu, Liu, Zhang, Liu, et al., 2019) (Table 2).

Similarly, kiwi seed oil improves insulin and glucose resistance by reducing the homeostatic model for assessing insulin resistance (HOMA-IR) index (Qu, Liu, Zhang, Liu, et al., 2019). These effects could be attributed to the low absorption of lipids through the inhibition of pancreatic lipase and to the increased lipolysis in fat cells or adipocytes (J. Kim, Jang, Kim, & Kim, 2009). In this sense, other authors have affirmed the *A. chinensis* seeds lipid reduction potential (Latocha, 2017). Additionally, the fiber contribution of kiwis causes a delay in the digestion of carbohydrates since their swelling action in the digestion process delays the rate of diffusion of glucose (Mishra & Monro, 2012). Besides, phenolic compounds have been also suggested to be involved in this hypoglycemic property of kiwi (Mishra et al., 2017). On the other hand, it has been shown that the kiwi stems can inhibit the α-glucosidase enzyme, reducing high levels of postprandial blood glucose in diabetics (Lee et al., 2014; Wojdyło et al., 2017). In summary, the ingestion of kiwi is a beneficial habit that may help in the regulation of the glucose and insulin levels in blood, while offering protection against the development of cardiovascular diseases.

5. Sustainable recovery of kiwi: Applications

In sight of the phytochemical profile and biological properties of this fruit, by-products of kiwi are considered a great source of natural ingredients. Recovered molecules may be further utilized for the development of innovative products or replacement of synthetic molecules. Hence, biomolecules extracted from kiwi by-products are mainly aimed to be reutilized in food and nutraceutical sectors, although other industries like pharmaceutical or cosmetic also claim them (Almeida et al., 2018; Cyboran et al., 2014; X. He et al., 2019; Marangi et al., 2018; Pinto et al., 2020). The reutilization of these by-products would contribute to a stronger presence in the market of functional and sustainable products that prompt health benefits while reducing food waste, thus, promoting the application of a circular economy strategy (Latocha, 2017).

5.1. Food additives

Currently, food industry processes kiwi to offer different presentations to the consumer: canned, sliced, dried, juiced, as oil or as part of yogurts, milky drinks, baked products like biscuits, vinegar or wine, among others (X. He et al., 2019). The vast variety of kiwi-based products already commercialized reflects its great consumers' acceptance. It facilitates the addition of extracted biomolecules from kiwi into different matrices since it even may avoid the development of encapsulating procedures. Several authors have affirmed that kiwi extracts may be used as a natural ingredient for formulating innovative functional foods (Dias et al., 2020). The most abundant molecules in kiwi by-products aimed to act as food additives include citric acid, phenolic compounds, actinidin, and pectin.

Citric acid, abundantly present in kiwi tissues, is an organic acid widely used in food, pharmaceutical industries as an acidifying agent and flavor enhancer (Cassano, Donato, Conidi, & Drioli, 2008). The extraction of citric acid can be carried out through simple maceration procedures accompanied by stirring or sonication steps (Alim et al., 2019; Dias et al., 2020; Wojdyło et al., 2017). However, the use of more advance techniques based on ion exchange and membrane-based processes provide several vantages like lower energy consumption, higher selectivity, higher separation speed and lower recovery costs, and therefore, greater efficiency (Cassano et al., 2008). Citric acid has been quantified between 0.4 and 9.6 g/100 g of fw in pulp while just few determinations have been done in peels although showed very similar values (Dias et al., 2020; Wojdyło et al., 2017). Citric acid extracted from kiwi by-products could be reutilized in the kiwi industry itself as an inhibitor of the enzymatic reaction responsible for browning processes. In fact, citric acid, among other molecules, has been demonstrated to be able of reducing browning and preserving color parameters during osmotic-dehydration of kiwifruit slices (Bhat et al., 2021).

All kiwi tissues have been described as suitable materials for recovering phenolic compounds, mainly aimed to be applied as antioxidants in pharmaceutical, cosmetic and food sectors (Guthrie et al., 2020). The most efficient and green technique to obtain phenolic compounds is applying subcritical extraction using water. It allows to shorten the extraction time and obtain extracts with higher antioxidant activity compared to the compounds extracted by conventional techniques. Besides, water is an ideal solvent regarding its further utilization as food, cosmetic or pharmaceutical ingredient (Guthrie et al., 2020; Kheirkhah et al., 2019). Polyphenols obtained from kiwi may represent a replacement for synthetic antioxidant compounds, repeatedly associated with side effects. Indeed, kiwi-polyphenols possess strong antioxidant capacity capable of reducing oxidation processes. For instance, kiwi extracts applied to beef as natural preservative inhibited the formation of thiobarbituric acid reactive species and total volatile basic nitrogen and decreased fatty acid oxidation which in parallel avoided meat discoloration and provided stable texture while keeping sensorial properties (Jiao et al., 2020). Similar results were found when fermented products from camel's milk were fortified with kiwi puree. The radical scavenging activity and total phenolic content was maintained in samples containing 6% of kiwi after 21 storage days, which confirms its capacity as natural preservative (Soliman & Shehata, 2019).

Another compound of interest present in kiwi that can act as food additive is actinidin. Actinidin is an enzyme with cysteine protease activity investigated as tender agent. The fortification of beef meat with actinidin significantly increases the nitrogen solubility index and water holding capacity. These parameters induced an enhancement of the emulsion stability and the improvement of the texture and sensorial features of treated cattle beef slices. The tenderization capacity of actinidin seems to be related with the molecular modification of the myofibrillar components of beef, although it has not been demonstrated (Toohey, Kerr, Ven, & Hopkins, 2011). Similarly, pork meat marinaded with actinidin and stored up to 9 days showed higher amounts of desmin degradation and heat-soluble collagen accompanied by smaller sizes of myofibrillar particles. The sensorial properties of taste, flavor and juiciness were not affected by actinidin. Thus, actinidin also acts as tenderizer in pork muscle meat (Christensen et al., 2009). In addition to meat, actinidin has potential use as cost-effective coagulant, mainly in milk. A study showed that kiwi extract produced a casein clot clearly separated from the serum, remaining stable at room temperature up to two months (Grozdanovic, Burazer, & Gavrovic-Jankulovic, 2013). In this sense, other authors affirm that sheep and buffalo cheese coagulated with kiwi extract offers additional benefits since they displayed a higher content of polyphenols and phytosterols than cheese obtained with calf rennet (Serra et al., 2020). Apart from enhancing the nutraceutical properties of dairy products, actinidin also induces slight positive modifications in the aroma. Besides, actinidin offers an estimated yield of 10.6%, similar to calf rennet, becoming a good candidate as vegetable coagulant for producing mozzarella cheese (Puglisi, Petrone, & Lo Piero, 2014).

The average content of pectins in kiwi is around 2.2% to 3.3% (Wojdyło et al., 2017). Pectins may have an indirect function as preservative agent. Pectins extracted from kiwi peels were embedded into a biodegradable watermelon rind pectin film and used to wrap chicken meat up to 9 days. Results displayed lower lipid oxidation values than the control (Han & Song, 2021). Hence, kiwi extracts would permit the extension of the shelf-life product and reduce the use of synthetic additives. Kiwi seed protein has also been identified as a potential ingredient as a substitute for soy protein for food processing (Deng et al., 2014). Thus, kiwi by-products might be used on industrial scale for recovering natural biomolecules with flavor and/or additive properties capable of improving the quality and value of the final product and hence widely claimed by food, nutraceutical, pharmaceutical or cosmetic industries.

5.2. Nutraceuticals: Functional foods and prebiotics

The presence of certain bioactive compounds can exert positive health effects (Latocha, 2017). In this way, some authors affirm that certain compounds extracted from kiwi juice such as ascorbic acid, folic acid, citric acid, glutamic acid or polyphenols, can be used to fortify food and beverages (Cassano et al., 2008).

One of the most studied properties of kiwi is its prebiotic capacity since its dietary fiber can help to modulate bacterial populations of the colon and decrease the production of mutagens after the fermentation of dietary chemicals by intestinal bacteria (Parkar et al., 2018). Fiber and bioactive compounds extracted from kiwi skin and bagasse provide significant benefits such as pectin oligosaccharides with demonstrated prebiotic and antiglycan activities *in vitro* (Latocha et al., 2015; Soquetta et al., 2016). Micro-encapsulated kiwi powder supplementation in mice, verified its effect on gastrointestinal motility processes and constipation relief (Zhuang et al., 2019). The consumption of cooked starch with kiwis have been proved to delay the digestion and absorption of carbohydrates, conferring hypoglycemic properties (Martin, Cordiner, & Mcghie, 2017). Kiwi seed oil has been pointed as a potential ingredient for dietary supplements aimed to prevent obesity and hypercholesterolemia. It would reduce body weight, blood glucose levels and promote a lipid-lowering effect, while providing anti-inflammatory effects and improving the intestinal microbiota (Leontowicz et al., 2016; Qu, Liu, Zhang, Liu, et al., 2019). For this reason, the development of a kiwi supplement as prebiotic would be suitable due to its fiber content and the presence of short-chain fatty acids that delay the absorption of glucose (Mishra et al., 2017; Mishra & Monro, 2012).

Apart from the high fiber content, the presence of proteins in kiwi may allow the development of nutraceutical products. Indeed, actinidin was used to prepare a protease-based product to improve the digestion and/or delay glucose absorption for hypoglycemic purposes (Chalabi, Khademi, Yarani, & Mostafaie, 2014). Whereas kissper, a peptide obtained from kiwellin, can exert nutraceutical functions by modulating the permeability of the membrane (Meleleo et al., 2012). In this sense, some digestive health products based on kiwi extracts, like Zylax or Kiwi-Klenz, have been already commercialized (Latocha, 2017).

5.3. Therapeutic applications

Even though it is hard to establish the limit between kiwi beneficial and therapeutical properties, some authors have underlined certain therapeutical activities. For instance, *A. arguta* was described to possess anticholinergic activity and it was proposed as dietary supplement to alleviate ulcerative colitis and attenuate the inflammatory response (Lian et al., 2019; Wojdyło & Nowicka, 2019). Regarding its anti-inflammatory capacity, fresh kiwi may serve as treatment for the debridement of bedsores in mice with burns (Hafezi, Elmi, Naghibzadeh, Nouhi, & Naghibzadeh, 2010), oral supplement of kiwi-based products would reduce the severity of upper respiratory infections (S. J. M. Skinner et al., 2013) and a study confirmed its potential use for treating the inflammation in gout (Heo et al., 2018).

Other research works indicate that kiwi supplements may reduce high levels of stress for its great content in polyphenols, vitamin C, vitamin E and vitamin B9 that can favor their immune response (Leontowicz et al., 2016; Richardson et al., 2018; Stonehouse et al., 2013). Furthermore, as vitamin C enhances the response to antidepressants, it was suggested that an oral kiwi supplement would be an interesting adjunctive to with antidepressant treatments (Carr, Bozonet, Pullar, & Vissers, 2013; Moritz, Schmitz, Rodrigues, Dafre, & Cunha, 2020). In fact, an experiment established that moderate mood disorders may be improved by consuming two kiwis a day for two weeks (Carr et al., 2013).

5.4. Other applications

In addition to all the applications outlined above, the potential of kiwi waste is much broader. For example, recent studies have investigated the use of kiwi antioxidant molecules for the development of novel applications, such as natural food preservatives or active packaging (Han & Song, 2021; Jiao et al., 2020; Luzi et al., 2017).

Plant extracts enriched with antioxidants have a wide applicability as food additives for preventing lipid oxidation and microorganisms' growth (Pinto et al., 2020). Flowers are rich in volatile substances can be used as raw material for obtaining high quality honey (X. He et al., 2019; Matich et al., 2003). The skin is rich in high-quality pectin and phenolic compounds, which can be used as a functional ingredient for food products, or as an extractive material to obtain molecules with therapeutic potential (Dias et al., 2020). Seeds, rich in essential fatty acids, proteins and dietary fiber can be used in the food and health products industry (Garcia, Quek, & Winz, 2012). Besides, kiwis are the richest dietary source of lutein, a carotenoid associated with antioxidant properties which may be conveniently used in the food industry (Nishiyama et al., 2005). Furthermore kiwi-based antimicrobial products can delay the progression of bacterial and fungal resistance to traditional drugs (S. J. M. Skinner et al., 2013). In this context, active packaging represents an innovative strategy to revalorize kiwifruit residues through the recovery of biomolecules with antimicrobial and antioxidant properties. Indeed, few works developed an biodegradable and bioactive films using kiwi extracts as one of the core ingredients that provided antimicrobial and antioxidant activities to these containers (Han & Song, 2021; Luzi et al., 2017).

On the other hand, proanthocyanidins from kiwi skin have been proposed as insecticides, food preservatives and cosmetic additives, given their strong capacity to inhibit tyrosinase activity (Chai et al., 2014). Finally, kiwi pruning remains have been suggested as energy source, comparable to forest resources (Manzone et al., 2017) but they are also effective as therapy for canine dermatitis (Marsella et al., 2010). These are just a few examples of the studies developed using kiwi residues to provide an overview of the huge potential that would imply its recovery in terms of economic and environmental benefits, as well as the associated boost for the research and development of innovative kiwi-based products.

6. Conclusions and future perspectives

This review work contains a description of the biological properties and nutritional composition of the different botanical parts of the plant and the fruit (kiwi) of *Actinidia*. The aim is highlighting the wide range of possibilities of revaluing the residues generated from the industrial production of kiwi. All botanical parts have biological activities due to their various chemical components (phenolic compounds, volatile compounds, vitamins, minerals, dietary fiber, etc.), which have beneficial effects for health (antioxidants, anti-inflammatory, anti-cancer, prebiotics, anti-cholinergic, lipid-lowering, and anti-diabetics). Over the years, the biological properties of kiwi fruit have been studied both *in vivo* and *in vitro*, leaving aside the study of residues of the kiwi exploitation (skin, pruning, seeds, flowers, and roots). However, few studies show the high content of compounds with biological functions present in these by-products. In fact, their concentrations can even exceed the amounts of these phytochemicals in the pulp, as is the case of phenolic compounds in skin. Therefore, all the parts of the kiwi plant are potential sources of extraction of phytochemicals with biological properties beneficial to human health. In this sense, the residues from the cultivation and processing of kiwi could be revalued. They may be used and transformed for its inclusion into new commercial products which would favor a circular economy model recognized as environmentally friendly and cost-effective. Therefore, *Actinidia* fruits (kiwi) and its different botanical parts are a natural source of promising ingredients for food industry aimed to develop functional products for their application as natural food additives, such as pectins, softeners, milk coagulants, and colorants. In the pharmaceutical industry they may be used for developing fortified, functional, nutraceutical, or prebiotic foods. Finally, in cosmetics, they may represent a source of ecological pigments, or ingredients for dermatitis treatment and bleaches. In addition, they can be incorporated for active food packaging as antimicrobials and antioxidants or as cellulose precursors. Finally, from an energetic point of view, they can even be used as a novel form of energy production through pellets or in the production of bioethanol.

The different botanical parts of kiwi provide innumerable health benefits due to its rich and variable composition both in nutrients and bioactive. Hence, all of them can be used as an excellent source of natural ingredients that may be exploited for the development of functional products, among many other uses. Therefore, the multiple applications in which kiwi by-products can be used prompt their reutilization for improving the throughput of its production while reducing their environmental impact.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The research leading to these results was supported by MICINN supporting the Ramón y Cajal grant for M.A. Prieto (RYC-2017-22891); by Xunta de Galicia for supporting the program EXCELENCIA-ED431F 2020/12, the post-doctoral grant of M. Fraga-Corral (ED481B-2019/096), the pre-doctoral grant of M. Carpena (ED481A 2021/313), the program BENEFICIOS DO CONSUMO DAS ESPECIES TINTORERA-(CO-0019-2021) that supports the work of F. Chamorro and by the program Grupos de Referencia Competitiva (GRUPO AA1-GRC 2018) that supports the work of J. Echave. Authors are grateful to Ibero-American Program on Science and Technology (CYTED—AQUA-CIBUS, P317RT0003), to the Bio Based Industries Joint Undertaking (JU) under grant agreement No 888003 UP4HEALTH Project (H2020-BBI-JTI-2019). The JU receives support from the European Union's Horizon 2020 research and innovation program and the Bio Based Industries Consortium. The project SYSTEMIC Knowledge hub on Nutrition and Food Security, has received funding from national research funding parties in Belgium (FWO), France (INRA), Germany (BLE), Italy (MIPAAF), Latvia (IZM), Norway (RCN), Portugal (FCT), and Spain (AEI) in a joint action of JPI HDHL, JPI-OCEANS and FACCE-JPI launched in 2019 under the ERA-NET ERA-HDHL (n° 696295). Funding for open access charge: Universidade de Vigo/CISUG.

References

Alim, A., Li, T., Nisar, T., Ren, D., Liu, Y., & Yang, X. (2020). Consumption of two whole kiwifruit (*Actinide chinensis*) per day improves lipid homeostasis, fatty acid metabolism and gut microbiota in healthy rats. *International Journal of Biological Macromolecules, 156*, 186–195. https://doi.org/10.1016/j.ijbiomac.2020.04.028

Alim, A., Li, T., Nisar, T., Ren, D., Zhai, X., Pang, Y., & Yang, X. (2019). Antioxidant, antimicrobial, and antiproliferative activity-based comparative study of peel and flesh polyphenols from *Actinidia chinensis*. *Food and Nutrition Research, 63*(3), 1–10. 10.29219/fnr.v63.1577.

Almeida, D., Pinto, D., Santos, J., Vinha, A. F., Palmeira, J., Ferreira, H. N., … Oliveira, M. B. P. P. (2018). Hardy kiwifruit leaves (Actinidia arguta): An extraordinary source of value-added compounds for food industry. Food Chemistry, 259(December 2017), 113–121. Doi: 10.1016/j.foodchem.2018.03.113.

R.E.A. Almond M. Grooten T. Petersen Living planet report 2020 2020 Bending the curve of biodiversity loss. WWF Gland, Switzerland Retrieved from https://livingplanet.panda.org/es-es/.

Ansell, J., Butts, C. A., Paturi, G., Eady, S. L., Wallace, A. J., Hedderley, D., & Gearry, R. B. (2015). Kiwifruit-derived supplements increase stool frequency in healthy adults: A randomized, double-blind, placebo-controlled study. *Nutrition Research, 35*(5), 401–408. https://doi.org/10.1016/j.nutres.2015.04.005

Baranowska-Wójcik, E., & Szwajgier, D. (2019). Characteristics and pro-health properties of mini kiwi (*Actinidia arguta*). *Horticulture Environment and Biotechnology, 60*(2), 217–225. https://doi.org/10.1007/s13580-018-0107-y

Basile, A., Vuotto, M. L., Violante, U., Sorbo, S., Martone, G., & Castaldo-Cobianchi, R. (1997). Antibacterial activity in Actinidia chinensis, Feijoa sellowiana and Aberia caffra. *International Journal of Antimicrobial Agents, 8*(3), 199–203. https://doi.org/10.1016/S0924-8579(97)00376-2

Bernardes, N. R., Talma, S. V., Sampaio, S. H., Nunes, C. R., Rangel de Almeida, J. A., & De Oliveira, D. B. (2011). Atividade Antioxidante E Fenois Totais De Frutas De Campos Dos Goytacazes Rj. *Biológicas & Saúde, 1*(1), 53–59. 10.25242/8868112011512.

Bhat, T. A., Rather, A. H., Hussain, S. Z., Naseer, B., Qadri, T., & Nazir, N. (2021). Efficacy of ascorbic acid, citric acid, ethylenediaminetetraacetic acid, and 4-hexylresorcinol as inhibitors of enzymatic browning in osmo-dehydrated fresh cut kiwis. *Journal of Food Measurement and Characterization, 15*(5), 4354–4370. https://doi.org/10.1007/s11694-021-01017-2

Blatchford, P., Stoklosinski, H., Walton, G., Swann, J., Gibson, G., Gearry, R., & Ansell, J. (2015). Kiwifruit fermentation drives positive gut microbial and metabolic changes irrespective of initial microbiota composition. *Bioactive Carbohydrates and Dietary Fibre, 6*(1), 37–45. https://doi.org/10.1016/j.bcdf.2015.07.001

Boland, M. (2013). Kiwifruit Proteins and Enzymes. Actinidin and Other Significant Proteins. In. *Advances in Food and Nutrition Research* (Vol. 68,, 59–80. https://doi.org/10.1016/B978-0-12-394294-4.00004-3

Brevik, A., Gaivão, I., Medin, T., Jørgenesen, A., Piasek, A., Elilasson, J., … Collins, A. R. (2011). Supplementation of a western diet with golden kiwifruits (Actinidia chinensis var . ' Hort 16A) effects on biomarkers of oxidation damage and antioxidant protection. Nutrition Journal, 10(1), 54. Doi: 10.1186/1475-2891-10-54.

Carr, A. C., Bozonet, S. M., Pullar, J. M., & Vissers, M. C. M. (2013). Mood improvement in young adult males following supplementation with gold kiwifruit, a high-vitamin C food. *Journal of Nutritional Science, 2*, 1–8. https://doi.org/10.1017/jns.2013.12

Cassano, A., Donato, L., Conidi, C., & Drioli, E. (2008). Recovery of bioactive compounds in kiwifruit juice by ultrafiltration. *Innovative Food Science and Emerging Technologies, 9*(4), 556–562. https://doi.org/10.1016/j.ifset.2008.03.004

Chai, W. M., Shi, Y., Feng, H. L., Xu, L., Xiang, Z. H., Gao, Y. S., & Chen, Q. X. (2014). Structure characterization and anti-tyrosinase mechanism of polymeric proanthocyanidins fractionated from kiwifruit pericarp. *Journal of Agricultural and Food Chemistry, 62*(27), 6382–6389. https://doi.org/10.1021/jf501009v

Chalabi, M., Khademi, F., Yarani, R., & Mostafaie, A. (2014). Proteolytic Activities of Kiwifruit Actinidin (Actinidia deliciosa cv. Hayward) on Different Fibrous and Globular Proteins : A Comparative Study of Actinidin with Papain. *Appl Biochem Biotechnol, 172*(8), 4025–4037. https://doi.org/10.1007/s12010-014-0812-7

Chen, A. G. Y., Offereins, M. S. L., Mulder, C. J., Frampton, C. M., & Gearry, R. B. (2018). A Pilot Study of the Effect of Green Kiwifruit on Human Intestinal Fermentation Measured by Hydrogen and Methane Breath Testing. *Journal of Medicinal Food, 21*(12), 1295–1298. https://doi.org/10.1089/jmf.2018.4179

Christensen, M., Tørngren, M. A., Gunvig, A., Rozlosnik, N., Lametsch, R., Karlsson, A. H., & Ertbjerg, P. (2009). Injection of marinade with actinidin increases tenderness of porcine M. biceps femoris and affects myofibrils and connective tissue. *Science of Food and Agriculture, 89*(9), 1607–1614. https://doi.org/10.1002/jsfa.3633

Cyboran, S., Oszmiański, J., & Kleszczyńska, H. (2014). Modification of the properties of biological membrane and its protection against oxidation by *Actinidia arguta* leaf extract. *Chemico-Biological Interactions, 222*, 50–59. https://doi.org/10.1016/j.cbi.2014.08.012

D'Evoli, L., Moscatello, S., Lucarini, M., Aguzzi, A., Gabrielli, P., Proietti, S., … Lombardi-Boccia, G. (2015). Nutritional traits and antioxidant capacity of kiwifruit (*Actinidia deliciosa* Planch., cv. Hayward) grown in Italy. *Journal of Food Composition and Analysis, 37*, 25–29. https://doi.org/10.1016/j.jfca.2014.06.012

Deng, J., Liu, Q., Zhang, C., Cao, W., Fan, D., & Yang, H. (2016). Extraction optimization of polyphenols from waste kiwi fruit seeds (*Actinidia chinensis* Planch.) and evaluation of its antioxidant and anti-inflammatory properties. *Molecules, 21*(7), 832. https://doi.org/10.3390/molecules21070832

Deng, J., Liu, Q., Zhang, Q., Zhang, C., Liu, D., Fan, D., & Yang, H. (2018). Comparative study on composition, physicochemical and antioxidant characteristics of different

varieties of kiwifruit seed oil in China. Food Chemistry, 264(February), 411–418. Doi: 10.1016/j.foodchem.2018.05.063.
Deng, J., Sun, T., Cao, W., Fan, D., Cheng, N.i., Wang, B., … Yang, H. (2014). Extraction Optimization and Functional Properties of Proteins from Kiwi Fruit (*Actinidia chinensis* Planch.) Seeds. *International Journal of Food Properties, 17*(7), 1612–1625. https://doi.org/10.1080/10942912.2013.772197
Dias, M., Caleja, C., Pereira, C., Calhelha, R. C., Kostic, M., Sokovic, M., … Ferreira, I. C. F. R. (2020). Chemical composition and bioactive properties of byproducts from two different kiwi varieties. Food Research International, 127(July 2019), 108753. Doi: 10.1016/j.foodres.2019.108753.
Eliseo, D. D., Pannucci, E., Bernini, R., Campo, M., Romani, A., Santi, L., & Velotti, F. (2019). In vitro studies on anti-inflammatory activities of kiwifruit peel extract in human THP-1 monocytes. Journal of Ethnopharmacology, 233(June 2018), 41–46. Doi: 10.1016/j.jep.2018.12.044.
FAO The State of World Fisheries and Aquaculture 2018 - Meeting the sustainable development goals. AqTHE STATE OF THE WORLD series of the Food and Agriculture Organization of the United Nations.uaculture Vol. 35 2018 https://doi.org/issn 10.
FAO. (2020). FAOSTAT: Crops and livestock products.
Fiorentino, A., D'Abrosca, B., Pacifico, S., Mastellone, C., Scognamiglio, M., & Monaco, P. (2009). Identification and assessment of antioxidant capacity of phytochemicals from kiwi fruits. *Journal of Agricultural and Food Chemistry, 57*(10), 4148–4155. https://doi.org/10.1021/jf900210z
Fotschki, B., Jurgoński, A., Juśkiewicz, J., & Zduńczyk, Z. (2015). Dietary supplementation with raspberry seed oil modulates liver functions, inflammatory state, and lipid metabolism in rats. *Journal of Nutrition, 145*(8), 1793–1799. https://doi.org/10.3945/jn.115.212407
Gammon, C. S., Kruger, R., Brown, S. J., Conlon, C. A., Von Hurst, P. R., & Stonehouse, W. (2014). Daily kiwifruit consumption did not improve blood pressure and markers of cardiovascular function in men with hypercholesterolemia. *Nutrition Research, 34*(3), 235–240. https://doi.org/10.1016/j.nutres.2014.01.005
García-Oliveira, P., Fraga-Corral, M., Pereira, A. G., Prieto, M. A., & Simal-Gandara, J. (2020). Solutions for the sustainability of the food production and consumption system. *Critical Reviews in Food Science and Nutrition, 1–17*. https://doi.org/10.1080/10408398.2020.1847028
Garcia, C. V., Quek, S.-Y., Stevenson, R. J., & Winz, R. A. (2012). Kiwifruit flavour: A review. *Trends in Food Science & Technology, 24*(2), 82–91. https://doi.org/10.1016/j.tifs.2011.08.012
Giangrieco, I., Proietti, S., Moscatello, S., Tuppo, L., Battistelli, A., La Cara, F., … Ciardiello, M. A. (2016). Influence of Geographical Location of Orchards on Green Kiwifruit Bioactive Components. *Journal of Agriculture and Food Chemistry, 64*(48), 9172–9179. https://doi.org/10.1021/acs.jafc.6b0393010.1021/acs.jafc.6b03930.s001
Grivennikov, S. I., Greten, F. R., & Karin, M. (2010). Immunity, Inflammation, and Cancer. *Cell, 140*(6), 883–899. https://doi.org/10.1016/j.cell.2010.01.025
Grozdanovic, M. M., Burazer, L., & Gavrovic-Jankulovic, M. (2013). Kiwifruit (Actinidia deliciosa) extract shows potential as a low-cost andefficient milk-clotting agent. *International Dairy Journal, 32*(1), 46–52. https://doi.org/10.1016/j.idairyj.2013.03.001
Guthrie, F., Wang, Y., Neeve, N., Young, S., Mohammadi, K., & Baroutian, S. (2020). Recovery of phenolic antioxidants from green kiwifruit peel using subcritical water extraction. *Food and Bioproducts Processing, 122*, 136–144. https://doi.org/10.1016/j.fbp.2020.05.002
Hafezi, F., Elmi, H., Naghibzadeh, B., Nouhi, A., & Naghibzadeh, G. (2010). Actinidia deliciosa (kiwifruit), a new drug for enzymatic debridement of acute burn wounds. *Burns, 36*(3), 352–355. https://doi.org/10.1016/j.burns.2009.04.021
Han, H.-S., & Song, K. B. (2021). Antioxidant properties of watermelon (*Citrullus lanatus*) rind pectin films containing kiwifruit (*Actinidia chinensis*) peel extract and their application as chicken thigh packaging. *Food Packaging and Shelf Life, 28*, Article 100636. 10.1016/j.fpsl.2021.100636.
He, J., Ma, B. Z., Zhao, T., Wang, W., Wei, F. L., Lu, J., & Zhang, X. L. (2014). Chemical constituents from the roots of *Actinidia chinensis*. *Chinese Pharmaceutical Journal, 49* (3), 184–186. 10.11669/cpj.2014.03.005.
He, X., Fang, J., Chen, X., Zhao, Z., Li, Y., Meng, Y., & Huang, L. (2019). Actinidia chinensis Planch.: A review of chemistry and pharmacology. *Frontiers in Pharmacology, 10*(OCT), 1–18. https://doi.org/10.3389/fphar.2019.01236
Henare, S. J. (2015). *The Nutritional Composition of Kiwifruit (Actinidia spp.). In Nutritional Composition of Fruit Cultivars* (pp. 337–370). Elsevier Inc..
Henriques, J., Luis, P., Pacheco, R., Helena, M., & Luísa, M. (2018). Journal of King Saud University – Science Phenolic compounds from Actinidia deliciosa leaves : Caco-2 permeability, enzyme inhibitory activity and cell protein profile studies. *Journal of King Saud University - Science, 30*(4), 513–518. https://doi.org/10.1016/j.jksus.2017.07.007
Heo, K. H., Sun, X., Shim, D. W., Kim, M. K., Koppula, S., Yu, S. H., … Lee, K. H. (2018). Actinidia arguta extract attenuates inflammasome activation: Potential involvement in NLRP3 ubiquitination. Journal of Ethnopharmacology, 213(July 2017), 159–165. Doi: 10.1016/j.jep.2017.11.023.
Hirsch, A.-M., Longeon, A., & Guyot, M. (2002). Fraxin and esculin: Two coumarins specific to *Actinidia chinensis* and *A. deliciosa* (kiwifruit). *Biochemical Systematics and Ecology, 30*(1), 55–60.
Huang, H. (2016). Kiwifruit. Kiwifruit: The Genus ACTINIDIA. Elsevier. https://doi.org/10.1016/C2014-0-02728-1.
Hunter, D. C., Skinner, M. A., & Ferguson, A. R. (2016). Kiwifruit and health. In Fruits, Vegetables, and Herbs: Bioactive Foods in Health Promotion (pp. 239–269). Elsevier Inc. Doi: 10.1016/B978-0-12-802972-5.00012-3.
Hunter, D. C., Skinner, M. A., Wolber, F. M., Booth, C. L., Loh, J. M. S., Wohlers, M., … Kruger, M. C. (2012). Consumption of gold kiwifruit reduces severity and duration of selected upper respiratory tract infection symptoms and increases plasma vitamin C concentration in healthy older adults. *British Journal of Nutrition, 108*(7), 1235–1245. https://doi.org/10.1017/S0007114511006659
Ikken, Y., Morales, P., Martínez, A., Marín, M. L., Haza, A. I., & Cambero, M. I. (1999). Antimutagenic Effect of Fruit and Vegetable Ethanolic Extracts against N-Nitrosamines Evaluated by the Ames Test. *Journal of Agricultural and Food Chemistry, 47*(8), 3257–3264. https://doi.org/10.1021/jf990166n
Jiao, Y., Young, S., Gu, M., Guo, Y., & Liu, Y. (2020). Polyphenols from thinned young kiwifruit as natural antioxidant: Protective effects on beef oxidation , physicochemical and sensory properties during storage. Food Control, 108(April 2019), 106870. Doi: 10.1016/j.foodcont.2019.106870.
Jimenez-Lopez, C., Fraga-Corral, M., Carpena, M., García-Oliveira, P., Echave, J., Pereira, A. G., … Simal-Gandara, J. (2020). Agriculture waste valorisation as a source of antioxidant phenolic compounds within a circular and sustainable bioeconomy. *Food & Function, 11*(6), 4853–4877. https://doi.org/10.1039/D0FO00937G
Karlsen, A., Svendsen, M., Seljeflot, I., Laake, P., Duttaroy, A. K., Drevon, C. A., … Blomhoff, R. (2013). Kiwifruit decreases blood pressure and whole-blood platelet aggregation in male smokers. *Journal of Human Hypertension, 27*(2), 126–130. https://doi.org/10.1038/jhh.2011.116
Kaur, L., Rutherfurd, S. M., Moughan, P. J., Drummond, L., & Boland, M. J. (2010). Actinidin enhances protein digestion in the small intestine as assessed using an in vitro digestion model. *Journal of Agricultural and Food Chemistry, 58*(8), 5074–5080. https://doi.org/10.1021/jf903835g
Kheirkhah, H., Baroutian, S., & Young, S. (2019). Evaluation of bioactive compounds extracted from Hayward kiwifruit pomace by subcritical water extraction. *Food and Bioproducts Processing, 115*, 143–153. https://doi.org/10.1016/j.fbp.2019.03.007
Kim, G., Lee, J. Y., & Auh, J. (2019). Metabolomic Screening of Anti-Inflammatory Compounds from the Leaves of *Actinidia arguta*. *Foods, 8*(2), 47. https://doi.org/10.3390/foods8020047
Kim, H. Y., Hwang, K. W., & Park, S. Y. (2014). Extracts of *Actinidia arguta* stems inhibited LPS-induced inflammatory responses through nuclear factor-κB pathway in Raw 264.7 cells. *Nutrition Research, 34*(11), 1008–1016. https://doi.org/10.1016/j.nutres.2014.08.019
Kim, J., Jang, D. S., Kim, H., & Kim, J. S. (2009). Anti-lipase and Lipolytic Activities of Ursolic Acid Isolated from the Roots of *Actinidia arguta*. *Arch Pharm Res, 32*(7), 983–987. https://doi.org/10.1007/s12272-009-1702-3
Kim, Y. M., Park, Y. S., Park, Y. K., Ham, K. S., Kang, S. G., Shafreen, R. M. B., … Gorinstein, S. (2020). Characterization of bioactive ligands with antioxidant properties of kiwifruit and persimmon cultivars using in vitro and in silico studies. *Applied Sciences (Switzerland), 10*(12), 1–15. https://doi.org/10.3390/APP10124218
Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling, 127*, 221–232. https://doi.org/10.1016/J.RESCONREC.2017.09.005
Latocha, P. (2017). The Nutritional and Health Benefits of Kiwiberry *Actinidia arguta*–a Review. *Plant Foods for Human Nutrition, 72*(4), 325–334. https://doi.org/10.1007/s11130-017-0637-y
Latocha, P., Łata, B., & Stasiak, A. (2015). Phenolics, ascorbate and the antioxidant potential of kiwiberry vs. common kiwifruit: The effect of cultivar and tissue type. *Journal of Functional Foods, 19*, 155–163. https://doi.org/10.1016/j.jff.2015.09.024
Lee, J., Sowndhararajan, K., Kim, M., Kim, J., Kim, D., Kim, S., … Jhoo, J. (2014). Antioxidant, inhibition of a-glucosidase and suppression of nitric oxide production in LPS-induced murine macrophages by different fractions of Actinidia arguta stem. *Saudi Journal of Biological Sciences, 21*(6), 532–538. https://doi.org/10.1016/j.sjbs.2014.01.006
Leiva Sajuria, C. (2014). La agricultura y la ciencia. Idesia (Vol. 32). Roma. https://doi.org/10.4067/S0718-34292014000300001.
Leontowicz, H., Leontowicz, M., Latocha, P., Jesion, I., Park, Y.-S., Katrich, E., … Gorinstein, S. (2016). Bioactivity and nutritional properties of hardy kiwi fruit *Actinidia arguta* in comparison with *Actinidia deliciosa* "Hayward" and *Actinidia eriantha* "Bidan". *Food Chemistry, 196*, 281–291. https://doi.org/10.1016/j.foodchem.2015.08.127
Lian, L., Zhang, S., Yu, Z., Ge, H., Qi, S., Zhang, X., … Gao, H. (2019). The dietary freeze-dried fruit powder of: Actinidia arguta ameliorates dextran sulphate sodium-induced ulcerative colitis in mice by inhibiting the activation of MAPKs. *Food and Function, 10*(9), 5768–5778. https://doi.org/10.1039/C9FO00664H
López-Sobaler, A. M., Aparicio Vizuete, A., & Ortega Anta, R. M. (2016). Beneficios nutricionales y sanitarios asociados al consumo de kiwi. *Nutricion Hospitalaria, 33*, 21–25. 10.20960/nh.340.
Luzi, F., Fortunati, E., Giovanale, G., Mazzaglia, A., Torre, L., & Mariano, G. (2017). Cellulose nanocrystals from *Actinidia deliciosa* pruning residues combined with carvacrol in PVA CH films with antioxidant/antimicrobial properties for packaging applications. *International Journal of Biological Macromolecules, 104*, 43–55. https://doi.org/10.1016/j.ijbiomac.2017.05.176
Lv, J., Wang, L., Shen, H., & Wang, X. (2018). Regulatory roles of OASL in lung cancer cell sensitivity to *Actinidia chinensis* Planch root extract (acRoots). *Cell Biology and Toxicology, 34*(3), 207–218.
Manzone, M., Gioelli, F., & Balsari, P. (2017). Kiwi clear-cut: First evaluation of recovered biomass for energy production. *Energies, 10*(11), 1837. https://doi.org/10.3390/en10111837
Marangi, F., Pinto, D., Francisco, L. D., Alves, R. C., Puga, H., Sut, S., … Oliveira, M. B. P. P. (2018). Hardy kiwi leaves extracted by multi-frequency multimode modulated technology : A sustainable and promising by-product for

industry. *Food Research International, 112*(June), 184–191. https://doi.org/10.1016/j.foodres.2018.06.029

Marsella, R., Messinger, L., Zabel, S., Rosychuck, R., Griffin, C., Cronin, P. O., … Stull, D. (2010). A randomized, double-blind, placebo-controlled study to evaluate the effect of EFF1001, an Actinidia arguta (hardy kiwi) preparation, on CADESI score and pruritus in dogs with mild to moderate atopic dermatitis. Veterinary Dermatology, 21(1), 50–57. Doi: 10.1111/j.1365-3164.2009.00773.x.

Martin, H., Cordiner, S. B., & Mcghie, T. K. (2017). Function Kiwifruit actinidin digests salivary amylase but not gastric lipase, 3339–3345. Doi: 10.1039/c7fo00914c.

Matich, A. J., Young, H., Allen, J. M., Wang, M. Y., Fielder, S., Mcneilage, M. A., & Macrae, E. A. (2003). *Actinidia arguta*: Volatile compounds in fruit and flowers. *Phytochemistry, 63*(3), 285–301. https://doi.org/10.1016/S0031-9422(03)00142-0

Meleleo, D., Gallucci, E., Notarachille, G., Sblano, C., Schettino, A., & Micelli, S. (2012). Studies on the Effect of Salts on the Channel Activity of Kissper, a Kiwi Fruit Peptide. *The Open Nutraceuticals Journal, 5*, 136–145.

Mishra, S., Edwards, H., Hedderley, D., Podd, J., & Monro, J. (2017). Kiwifruit Non-Sugar Components Reduce Glycaemic Response to Co-Ingested Cereal in Humans. *Nutrients, 9*(11), 1195. https://doi.org/10.3390/nu9111195

Mishra, S., & Monro, J. (2012). Kiwifruit remnants from digestion in vitro have functional attributes of potential importance to health. *FOOD CHEMISTRY, 135*(4), 2188–2194. https://doi.org/10.1016/j.foodchem.2012.06.102

Mohammed A Hussein, S. M. O. (2014). Purslane Seeds Fixed Oil as a Functional Food in Treatment of Obesity Induced by High Fat Diet in Obese Diabetic Mice. Journal of Nutrition & Food Sciences, 5(1), 1000332. Doi: 10.4172/2155-9600.1000332.

Montoya, C. A., Rutherfurd, S. M., Olson, T. D., Purba, A. S., Drummond, L. N., Boland, M. J., & Moughan, P. J. (2014). Actinidin from kiwifruit (*Actinidia deliciosa* cv. Hayward) increases the digestion and rate of gastric emptying of meat proteins in the growing pig. *British Journal of Nutrition, 111*(6), 957–967. https://doi.org/10.1017/S0007114513003401

Moritz, B., Schmitz, A. E., Rodrigues, A. Lúcia. S., Dafre, A. L., & Cunha, M. P. (2020). ScienceDirect The role of vitamin C in stress-related disorders. *The Journal of Nutritional Biochemistry, 85*, 108459. https://doi.org/10.1016/j.jnutbio.2020.108459

Nie, R., Zhang, Y., Zhang, H., Jin, Q., Wu, G., & Wang, X. (2020). Effect of different processing methods on physicochemical properties, chemical compositions and *in vitro* antioxidant activities of *Paeonia lactiflora* Pall seed oils. *Food Chemistry, 332*, 127408. https://doi.org/10.1016/j.foodchem.2020.127408

Nishimura, M., Okimasu, Y., Miyake, N., Tada, M., Hida, R., Negishi, T., & Arimoto-Kobayashi, S. (2016). Inhibitory effect of Actinidia arguta on mutagenesis, inflammation and two-stage mouse skin tumorigenesis. *Genes and Environment, 38* (1). https://doi.org/10.1186/s41021-016-0053-9

Nishiyama, I. (2007). Fruits of the Actinidia Genus. *Advances in Food and Nutrition Research, 52*(6), 293–324. https://doi.org/10.1016/S1043-4526(06)52006-6

Nishiyama, I., Fukuda, T., & Oota, T. (2005). Genotypic Differences in Chlorophyll, Lutein, and -Carotene Contents in the Fruits of Actinidia Species. *J. Agric. Food Chem, 53*(16), 6403–6407. https://doi.org/10.1021/jf050785y

Nishiyama, I., Yamashita, Y., Yamanaka, M., Shimohashi, A., Fukuda, T., & Oota, T. (2004). Varietal Difference in Vitamin C Content in the Fruit of Kiwifruit and Other Actinidia Species. *J. Agric. Food Chem., 52*(17), 5472–5475. https://doi.org/10.1021/jf049398z

Park, Y.-S., Namiesnik, J., Vearasilp, K., Leontowicz, H., Leontowicz, M., Barasch, D., … Gorinstein, S. (2014). Bioactive compounds and the antioxidant capacity in new kiwi fruit cultivars. *Food Chemistry, 165*, 354–361. https://doi.org/10.1016/j.foodchem.2014.05.114

Parkar, S. G., Simmons, L., Herath, T. D., Phipps, J. E., Trower, T. M., Hedderley, D. I., … Ingram, J. R. (2018). Evaluation of the prebiotic potential of five kiwifruit cultivars after simulated gastrointestinal digestion and fermentation with human faecal bacteria. *International Journal of Food Science & Technology, 53*(5), 1203–1210. https://doi.org/10.1111/ijfs.2018.53.issue-510.1111/ijfs.13697

Peng, Y., Cordiner, S. B., Sawyer, G. M., McGhie, T. K., Espley, R. V., Allan, A. C., & Hurst, R. D. (2020). Kiwifruit with high anthocyanin content modulates NF-κB activation and reduces CCL11 secretion in human alveolar epithelial cells. *Journal of Functional Foods, 65*, 103734. https://doi.org/10.1016/j.jff.2019.103734

Pérez-Burillo, S., Oliveras, M. J., Quesada, J., Rufián-Henares, J. A., & Pastoriza, S. (2018). Relationship between composition and bioactivity of persimmon and kiwifruit. Food Research International, 105(September 2017), 461–472. Doi: 10.1016/j.foodres.2017.11.022.

Picchi, G., Lombardini, C., Pari, L., & Spinelli, R. (2018). Physical and chemical characteristics of renewable fuel obtained from pruning residues. *Journal of Cleaner Production, 171*, 457–463. https://doi.org/10.1016/j.jclepro.2017.10.025

Pinto, D., Delerue-matos, C., & Rodrigues, F. (2020). Bioactivity, phytochemical profile and pro-healthy properties of *Actinidia arguta*: A review. *Food Research International, 136*(May), Article 109449. https://doi.org/10.1016/j.foodres.2020.109449

Prior, R. L., Gu, L., Wu, X., Jacob, R. A., Sotoudeh, G., Kader, A. A., & Cook, R. A. (2007). Plasma antioxidant capacity changes following a meal as a measure of the ability of a food to alter in vivo antioxidant status. *Journal of the American College of Nutrition, 26* (2), 170–181. https://doi.org/10.1080/07315724.2007.10719599

Puglisi, I., Petrone, G., & Lo Piero, A. R. (2014). A kiwi juice aqueous solution as coagulant of bovine milk and its potential in Mozzarella cheese manufacture. *Food and Bioproducts Processing, 92*(1), 67–72. https://doi.org/10.1016/j.fbp.2013.07.011

Qu, L., Liu, Q., Zhang, Q., Liu, D., Zhang, C., Fan, D., & Deng, J. (2019). Kiwifruit seed oil ameliorates inflammation and hepatic fat metabolism in high-fat diet-induced obese mice. Journal of Functional Foods, 52(August 2018), 715–723. Doi: 10.1016/j.jff.2018.12.003.

Qu, L., Liu, Q., Zhang, Q., Tuo, X., Fan, D., Deng, J., & Yang, H. (2019). Kiwifruit seed oil prevents obesity by regulating inflammation, thermogenesis, and gut microbiota in high-fat diet-induced obese C57BL/6 mice. *Food and Chemical Toxicology, 125*, 85–94. https://doi.org/10.1016/j.fct.2018.12.046

Reiss, R., Johnston, J., Tucker, K., DeSesso, J. M., & Keen, C. L. (2012). Estimation of cancer risks and benefits associated with a potential increased consumption of fruits and vegetables. *Food and Chemical Toxicology, 50*(12), 4421–4427. https://doi.org/10.1016/j.fct.2012.08.055

Richardson, D. P., Ansell, J., & Drummond, L. N. (2018). The nutritional and health attributes of kiwifruit: A review. *European Journal of Nutrition, 57*(8), 2659–2676. https://doi.org/10.1007/s00394-018-1627-z

Salama, Z. A., Aboul-Enein Ahmed, M., Gaafar Alaa, A., Faten, A. E., Aly Hanan, F., Asker Mohsen, S., & Ahmed Habiba, A. (2018). Active constituents of Kiwi (*Actinidia deliciosa* Planch) peels and their biological activities as antioxidant, antimicrobial and anticancer. *Research Journal of Chemistry and Environment, 22*(9), 52–59.

Salinero, C., & Sainz, M. J. (2005). *EFA 40/05: Técnicas de cultivo de kiwi.* Estación Fitopatolóxica de Areeiro.

Serra, A., Conte, G., Corrales-Retana, L., Casarosa, L., Ciucci, F., & Mele, M. (2020). Nutraceutical and technological properties of buffalo and sheep cheese produced by the addition of kiwi juice as a coagulant. *Foods, 9*(5), 637. https://doi.org/10.3390/foods9050637

Shu, Q., Mendis De Silva, U., Chen, S., Peng, W., Ahmed, M., Lu, G., … Drummond, L. (2008). Kiwifruit extract enhances markers of innate and acquired immunity in a murine model. *Food and Agricultural Immunology, 19*(2), 149–161. https://doi.org/10.1080/09540100802117198

Skinner, M. A., Bentley-Hewitt, K., Rosendale, D., Naoko, S., & Pernthaner, A. (2013). Effects of Kiwifruit on Innate and Adaptive Immunity and Symptoms of Upper Respiratory Tract Infections. In Nutritional Benefits of Kiwifruit book series of Advances in Food and Nutrition Research (1st ed., Vol. 68, pp. 301–320). Elsevier Inc. Doi: 10.1016/B978-0-12-394294-4.00017-1.

Skinner, S. J. M., Hunter, D., Cho, S., & Skinner, M. (2013). The Potential Health Benefits of the Subtropical Fruits Kiwifruit, Feijoa and Tamarillo. In *In Bioactives in Fruit: Health Benefits and Functional Foods* (pp. 169–195).

Soliman, T. N., & Shehata, S. H. (2019). Characteristics of fermented camel's milk fortified with kiwi or avocado fruits. *Acta Scientiarum Polonorum, Technologia Alimentaria, 18*(1), 53–63. 10.17306/J.AFS.2019.0602.

Soquetta, M. B., Stefanello, F. S., Huerta, K. D. M., Monteiro, S. S., Da Rosa, C. S., & Terra, N. N. (2016). Characterization of physiochemical and microbiological properties, and bioactive compounds, of flour made from the skin and bagasse of kiwi fruit (*Actinidia deliciosa*). *Food Chemistry, 199*, 471–478. https://doi.org/10.1016/j.foodchem.2015.12.022

Stonehouse, W., Gammon, C. S., Beck, K. L., Conlon, C. A., Hurst, P. R. Von, & Kruger, R. (2013). Kiwifruit : our daily prescription for health. Canadian Journal of Physiology and Pharmacology, 91(6), 442–447.

Sun, Q., Zhang, B., Yan, Q., & Jiang, Z. (2016). Comparative analysis on the distribution of protease activities among fruits and vegetable resources. *Food Chemistry, 213*, 708–713. https://doi.org/10.1016/j.foodchem.2016.07.029

Tajan, M., & Vousden, K. H. (2020). Dietary Approaches to Cancer Therapy. *Cancer Cell, 37*(6), 767–785. https://doi.org/10.1016/j.ccell.2020.04.005

Talens, P., Escriche, I., Martínez-Navarrete, N., & Chiralt, A. (2003). Influence of osmotic dehydration and freezing on the volatile profile of kiwi fruit. *Food Research International, 36*(6), 635–642. https://doi.org/10.1016/S0963-9969(03)00016-4

Toohey, E. S., Kerr, M. J., Ven, R. Van De, & Hopkins, D. L. (2011). The effect of a kiwi fruit based solution on meat traits in beef M. semimembranosus (topside). MESC, 88 (3), 468–471. Doi: 10.1016/j.meatsci.2011.01.028.

Toop, T. A., Ward, S., Oldfield, T., Hull, M., Kirby, M. E., & Theodorou, M. K. (2017). AgroCycle - Developing a circular economy in agriculture. *Energy Procedia, 123*, 76–80. https://doi.org/10.1016/j.egypro.2017.07.269

Traka, M. H., & Mithen, R. F. (2011). Plant Science and Human Nutrition : Challenges in Assessing Health-Promoting Properties of Phytochemicals, 23(July), 2483–2497, Doi: 10.1105/tpc.111.087916.

Trinh, L. T. P., Choi, Y. S., & Bae, H. J. (2018). Production of phenolic compounds and biosugars from flower resources via several extraction processes. *Industrial Crops and Products, 125*(September), 261–268. https://doi.org/10.1016/j.indcrop.2018.09.008

Wang, Y., Li, L., Liu, H., Zhao, T., Meng, C., Liu, Z., & Liu, X. (2018). Bioactive compounds and in vitro antioxidant activities of peel, flesh and seed powder of kiwi fruit. *International Journal of Food Science and Technology, 53*(9), 2239–2245. https://doi.org/10.1111/ijfs.2018.53.issue-910.1111/ijfs.13812

Wei, L.-B., Ma, S.-Y., Liu, H.-X., Huang, C.-S., & Liao, N. (2018). Cytotoxic Triterpenoids from Roots of Actinidia chinensis. *Chem Biodivers, 15*(2), e1700454. https://doi.org/10.1002/cbdv.v15.210.1002/cbdv.201700454

Wojdyło, A., & Nowicka, P. (2019). Anticholinergic effects of Actinidia arguta fruits and their polyphenol content determined by liquid chromatography-photodiode array detector-quadrupole/time of flight-mass spectrometry (LC-MS-PDA-Q/TOF). Food Chemistry, 271(July 2018), 216–223. Doi: 10.1016/j.foodchem.2018.07.084.

Wojdyło, A., Nowicka, P., Oszmiański, J., & Golis, T. (2017). Phytochemical compounds and biological effects of Actinidia fruits. *Journal of Functional Foods, 30*, 194–202. https://doi.org/10.1016/j.jff.2017.01.018

Yang, H., Hu, M., Fan, D., Zhang, J., Deng, J., & Zhang, R. (2014). Conformational Study of Kiwi Fruit (*Actinidia chinensis* Planch.) Seed Protein Isolates by Fluorescence Spectroscopy. *Asian Journal of Chemistry, 26*(19), 6435–6439.

Yang, H., Lee, Y.-C., Han, K.-S., Singh, H., Yoon, M., Park, J.-H., … Cho, S. (2013). Green and gold kiwifruit peel ethanol extracts potentiate pentobarbital-induced sleep in mice via a GABAergic mechanism. *Food Chemistry, 136*(1), 160–163. https://doi.org/10.1016/j.foodchem.2012.07.111

Yu, A.-N., Tian, D.-T., Qu, W.-Y., Tan, Z.-W., & Song, X.-J. (2009). Chemical composition of the essential oil of the roots of *Actinidia chinensis* from China. *Chemistry of Natural Compounds, 45*(1), 108–109.

Yu, X.-L., Liu, C.-J., Liu, Y., Tan, C.-H., & Liu, Y.-Y. (2015). *Actinidia arguta* polysaccharide induces apoptosis in Hep G2 cells. *Advance Journal of Food Science and Technology, 7*(11), 857–863.

Zhuang, Z., Chen, M., Niu, J., Qu, N., Ji, B., Duan, X., Liu, Z., Liu, X., Wang, Y., & Zhao, B. (2019). The Manufacturing Process of Kiwifruit Fruit Powder with High Dietary Fiber and its Laxative Effect. *Molecules, 24*(21), 3813. https://doi.org/10.3390/molecules24213813

Zuo, L.-L., Wang, Z.-Y., Fan, Z.-L., Tian, S.-Q., & Liu, J.-R. (2012). Evaluation of antioxidant and antiproliferative properties of three Actinidia (*Actinidia kolomikta, Actinidia arguta, Actinidia chinensis*) extracts *in vitro*. *International Journal of Molecular Sciences, 13*(5), 5506–5518. https://doi.org/10.3390/ijms13055506