Gesunde Pflanzen (2018) 70:65–74
https://doi.org/10.1007/s10343-018-0416-1

REVIEW ARTICLE

Phytochemical Composition and Potential Use of *Rubus* Species

Brigitte Liliana Moreno-Medina[1] · **Fánor Casierra-Posada**[2] · **Joseph Cutler**[3]

Received: 19 December 2017 / Accepted: 19 February 2018 / Published online: 6 March 2018

Abstract

Plants produce a number of compounds that are vital to the growth and development processes (primary metabolites) of cells and plant health. In addition to this type of metabolism, plants perform various processes that lead to taxonomically specific formation of compounds (secondary metabolites) that are a vital part of the human diet. Historically, plants have been used for their multiple benefits for the prevention and treatment of diseases. *Rubus* species are cultivated on all continents, at various altitudes, from temperate forests to tropical climates, and have edible and economically important fruits. The present review describes the polyphenols as the group of chemical substances that is most frequently found in species of the genus *Rubus*. Additionally, reference is made to nutritional components such as proteins, fats, calories, vitamins, fiber and minerals. Biochemical characteristics such as pH, total soluble solids and titratable acidity, and phytochemical compounds such as fatty acids, anthocyanins, total phenols, ellagitannis and saponins, among others, are presented. The uses of these compounds found in fruits, leaves, stems and seeds of *Rubus* species plants are considered, in regard to prevention and management of diseases and agroindustrial and pharmaceutical potential.

Keywords Polyphenols · Anthocyanins · Antioxidants · Nutrients · Phytochemicals

✉ Fánor Casierra-Posada
fanor.casierra@uptc.edu.co

1 Faculty of Sciences, Universidad Pedagógica y Tecnológica de Colombia (UPTC), Tunja, Colombia

2 Faculty of Agricultural Sciences, Research Group in Plant Ecophysiology, Universidad Pedagógica y Tecnológica de Colombia (UPTC), Tunja, Colombia

3 Lebenswissenschaftliche Fakultät, Fachgebiet Phytomedizin, Humboldt Universität, Berlin, Germany

Phytochemische Zusammensetzung und mögliche Verwendung von *Rubus*-Arten

Zusammenfassung
Pflanzen produzieren eine Anzahl von Verbindungen, die mit den Wachstums- und Entwicklungsprozessen (Primärmetaboliten) in Verbindung stehen, die für das Zell- und Pflanzenleben grundlegend sind. Parallel zu dieser Art von Metabolismus führen Pflanzen verschiedene Prozesse durch, die zu einer taxonomisch spezifischen Bildung von Verbindungen (Sekundärmetaboliten) führen, die ein wichtiger Bestandteil der menschlichen Ernährung sind. In der Vergangenheit wurden Pflanzen aufgrund ihrer vielfältigen Vorteile zur Vorbeugung und Behandlung von Krankheiten eingesetzt. *Rubus*-Arten werden auf allen Kontinenten, in verschiedenen Höhen, von gemäßigten Wäldern bis zu tropischen Klimazonen kultiviert und haben essbare und wirtschaftlich wichtige Früchte. Die vorliegende Übersicht beschreibt die Polyphenole als die Gruppe der chemischen Substanzen, die am häufigsten in Arten der Gattung *Rubus* gefunden wird. Zusätzlich wird Bezug genommen auf Nahrungsbestandteile wie Proteine, Fette, Kalorien, Vitamine, Ballaststoffe und Mineralien. Ebenso werden biochemische Eigenschaften wie pH, gesamtlösliche Feststoffe und titrierbare Säure und phytochemische Verbindungen wie Fettsäuren, Anthocyanine, Gesamtphenole, Ellagitannis und Saponine vorgestellt. Schließlich werden die Anwendungen dieser Verbindungen bei der Vorbeugung und Behandlung von Krankheiten in Betracht gezogen, wenn diese Substanzen in Früchten, Blättern, Stängeln und Samen von *Rubus*-Arten vorkommen. Auf diese Weise kann auf das agroindustrielle und pharmazeutische Potenzial dieser Arten geschlossen werden.

Schlüsselwörter Polyphenole · Anthocyane · Antioxidantien · Nährstoffe · Phytochemikalien

Introduction

Species belonging to the genus *Rubus* are grown on all continents, and have been identified at various altitudes, from temperate forests to tropical climates, however, only some species have edible and economically important fruits. The domesticated and wild species of this genus are characterized as rustic shrubs that have enormous genetic diversity (Cancino et al. 2011), recognized for the quality of their fruits. Various parts of the plant are consumed in different preparations for their medicinal and therapeutic properties.

Plants produce a wide range of compounds other than amino acids, simple sugars, polymers, nucleotides and fatty acids (primary metabolites), that are not directly related to the growth and development processes essential for cell life (Gershenzon and Dudareva 2007; Grajales-Conesa et al. 2011). In parallel, plants perform various processes similar to those of the primary metabolism that lead to the formation of compounds that are specific to taxonomic group and known as natural products or secondary metabolites (Gandhi et al. 2015). These compounds have no direct impact on photosynthesis, solute transport, respiration, differentiation, or carbohydrate formation, and plants can make use of secondary metabolites for their own defense, to attract pollinators, or to interact with their ecosystems (Taiz and Zeiger 2010; García 2004; Grajales-Conesa et al. 2011).

Secondary metabolites are produced in low quantities, and form depending on the phenological stage of the plant, the ecosystem services, and biotic or abiotic stress. In this sense, the secondary metabolism is responsible for biosynthesis, transformation and degradation of endogenous compounds through specialized proteins found in plants, and constitute a valuable group of compounds with pharmacological, medicinal and phytosanitary functions (Bérdy 2005; Sepúlveda et al. 2003). According to Taiz and Zeiger (2010), there are three main types of chemically different secondary metabolites: compounds derived from nitrogen, terpenes and phenols.

In this review, polyphenols are described as compounds commonly found in plants of the genus *Rubus*. Also, descriptions of other compounds reported in the tissues of *Rubus* spp are discussed. Plant proteins, fats, vitamins, fiber, minerals, total phenols, ellagitannis and saponins are presented, and finally, some pharmaceutical and agroindustrial uses are proposed for these species. The study of secondary metabolites in *Rubus* species, their contributions to the human and animal diet, and their biological activity or function as phytosanitary products contribute to a significant pharmaceutical and agroindustrial potential. This review also proposes practices for the agronomic management of production chains of blackberries and raspberries, emphasizing quality raw materials and highlighting the challenges for industrial production.

Nitrogen-Derived Compounds

In plants, secondary metabolites containing nitrogen are biosynthesized from common amino acids, and are well known for their defensive action against herbivores and their toxic and medicinal properties. Among the compounds that have nitrogen are alkaloids, cyanogenic glycosides, non-protein amino acids and glucosinolates (Gandhi et al. 2015; Azcón-Bieto and Talón 2008).

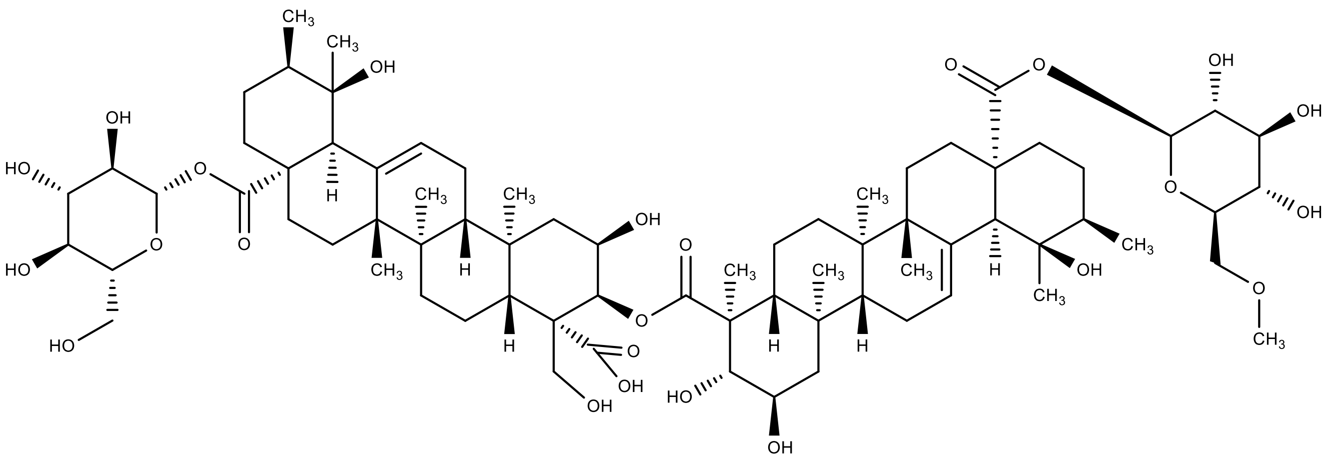

Fig. 1 Rubupungenoside A, a terpene present in the species *R. pungens*

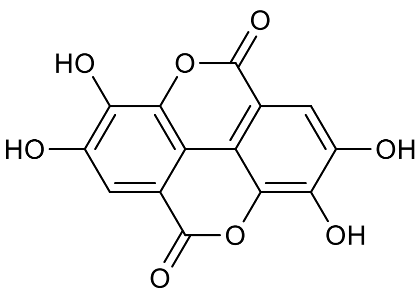

Fig. 2 Elagic acid, a polyphenol present in the species *Rubus idaeus*

Terpenes

In the plant kingdom, terpenes or isoprenoids form a huge group of secondary metabolites, which are insoluble in water, biosynthesized from acetyl-CoA or from glycolitic intermediates, and have an effect on plant growth. Terpenes are components of the cell membrane and act as complementary pigments. Examples of these compounds are gibberellins and abscisic acid (phytohormones), plastoquinone, chlorophyll phytol, carotenoids (tetraterpens), phytosterols, and dolichols (politerpens alcohols). Fig. 1 shows the pentacyclic triterpenoids and their glycosides, found in the species *R. pungens*, to which contraceptive and antibacterial properties are attributed in traditional Chinese medicine (Wang and Lin 2000).

Phenols

Phenols are compounds of aromatic structure with one or more hydroxyl groups, free or substituted, and can be found in a large part of the plant tissues of the *Rubus* species. The basic structure is phenol, however, most of these types of compounds are polyphenols, according to Rao and Snyder (2010).

At present, about 8000 phenolic compounds are known, among which are coumarins, phenolic quinones, stilbenes, lignans, and flavonoids (anthocyanins), the latter characteristic of the reddish colorations of plants that act as antioxidants. Fig. 2 shows an example of elagic acid present in the fruits of the species *R. idaeus* (Rao and Snyder 2010). In addition, some phenolic compounds play an important role in the defense of the plant (phytoalexins), intervene in the processes of flowering, pollination and even in the fixation of nitrogen, and can act upon the growth of plants through a mechanism that changes the endogenous levels of 3-indolacetic acid. It should be noted that the anthocyanin that occurs most frequently among species of the genus *Rubus* is cyanidin (Markakis 1982; Taiz and Zeiger 2010).

In recent works, defined physiological functions have been found for many secondary metabolites, which have been fundamental for the promotion of many species as functional foods. In addition, these metabolites are no longer considered vegetable wastes. They are now considered natural compounds involved in plant defense processes (phytoalexins) and in ecophysiological strategies related to processes such as pollination, mainly due to the pigments that generate striking colours in the flowers for the attraction of pollinating insects, and the floral aromas generated as a communication strategy between herbivores, pollinators and some natural enemies (Grajales-Conesa et al. 2011).

Botanical Description

There are around 750 species in the world that belong to the *Rubus* genus, the genus with the highest number of species within the Rosaceae family. Fig. 3 describes the taxonomy of this plant genus with contributions of different authors regarding its enormous diversity, economic importance and geographic distribution. This genus is divided into 12 sub-genera, of which the sub-genera *Idaeobatus* (Raspberries) and *Rubus* (Blackberries) have been domesticated

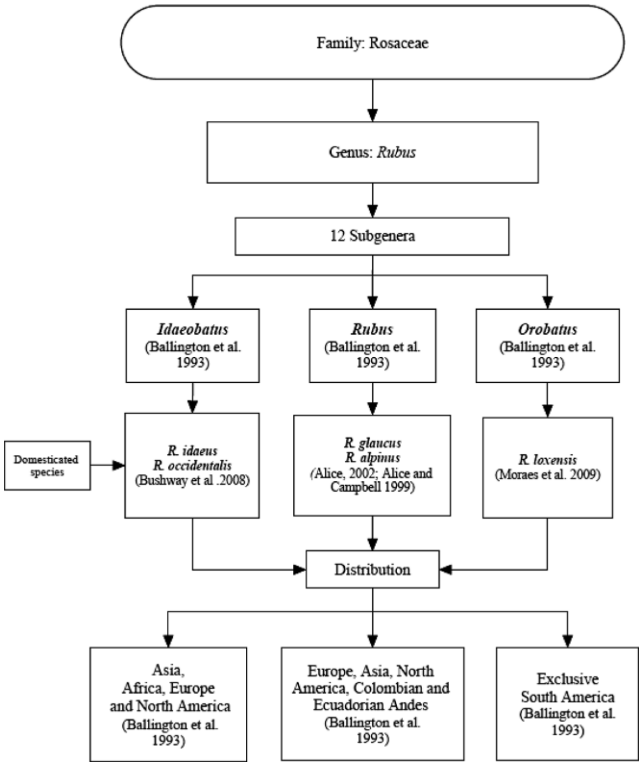

Fig. 3 Taxonomy and geographical distribution of some representatives of the *Rubus* genus

and make up a valuable group of raspberries, blackberries and strongly heterozygotic arctic fruit (Ayala et al. 2013; Bushway et al. 2008).

According to Ballington et al. (1993), the subgenus *Idaeobatus* has raspberry species that include *R. idaeus* and *R. occidentalis*, distributed in Europe, Asia, North America and Africa. The distribution of the subgenus *Rubus* is found in North America, Europe and Asia, and has taxa such as *R. glaucus* and *R. alpinus*, which were included in this subgenus after a phylogenetic analysis of nuclear ribosomal DNA with ITSs (internal transcribed spacer regions) (Alice and Campbell 1999; Alice 2002). The subgenus *Orobatus* is found only in South America: two such species are *R. loxensis* (threatened species) and *R. nubigenus* (Moraes et al. 2009). *Rubus, Orobatus*, and *Idaeobatus* are found in the Colombian and Ecuadorian Andes, demonstrating once again the enormous diversity that this genus of plants presents in the Andean mountain range.

Plants of the genus *Rubus* are characterized as being perennial subshrubs with reclining or scandent branches, they have prickles that are often erroneously called thorns, being thin to stout, straight or curved, and covered with simple white to red trichomes. Stems can be green, red or purple, leaves can have three or five leaflets, pinnate or simple, with simple or double serrate margins and persistent stipules, with terminal or axillary inflorescences, in clusters, panicles, or as solitary flowers (Kalkman 2004).

Pedicels or flowers can have flattened hypanthium, absent bracteoles, with five sepals persistent in the fruit and green plant parts with five white, pink or purple petals, numerous stamens, and a superior ovary, with 10 to 100 or more free, terminal style carpels. Fruits are in aggregates of drupes, either joined or free from the receptacle, and are yellow, orange, red or black-purple when ripe (Kalkman 2004).

Physiochemical Properties of Fruits

In 2014, according to the FAO (2017), in production of berries worldwide, Iran led with 313,880 t, followed by Mexico with 152,922 and Vietnam with 136,529 t respectively, while in 2016, 110,453 t of blackberries were produced in Colombia (Agronet 2017). These figures are an indicator of the great importance of blackberries among *Rubus* domesticated species. These fruits are in great demand in international markets due to their taste, colour and their therapeutic properties. For these reasons, it is important to mention the physicochemical characteristics or organoleptic properties that determine the quality for marketing of fresh produce and processing for agroindustrial use.

Table 1 shows the physicochemical properties of berries in some *Rubus* species. According to Gómez-Romero et al. (2010), some of the physicochemical changes are possibly related to solar radiation, temperature, nutrition of the plant, among others, and these in turn directly influence the quality and taste of the fruits. For this reason, in countries such as Italy, Venezuela, Peru, Colombia and Brazil, clear differences in the content of total soluble solids (TSS) ranging from 7 to 13 °Brix are reported. In the case of pH there are no marked differences between the different taxa and values are between 2.6 and 3.4. In the case of the total titratable acidity (TTA), marked fluctuations are evident in the different species which shows that agroindustrial processes for this type of fruit are successful, due to the organoleptic stability and the low microbial proliferation in juices and jam, due in part to pH and TTA values.

Nutritional Importance of the Species of the Genus *Rubus*

The daily requirement of nutrients in humans requires specific knowledge related to metabolism, digestion, absorption, retention, cellular transport and excretion, taking into account the storage capacity of each organ. Therefore, it can be stated that most of the fat-soluble vitamins and minerals are stored in adipose tissue, and in the liver and bones. On the contrary, water-soluble vitamins lack a specific deposit and only participate as enzymatic cofactors or active metabolites (Hernández 2004).

Table 1 Physicochemical characteristics of fruits in some *Rubus* species

Country Producer	Species	TSS (°Brix)	TTA	pH	Reference
			mg L^{-1}		
Italy	R. *ulmifolios* cv. *Black satin*	10.8	30.1	3.2	Rotundo et al. (1998)
	R. *ulmifolios* cv. *Smooth-stem*	11.4	28.8	3.1	
	R. idaeus cv. *Sumner*	12	29	3.2	
	R. idaeus cv. *Herbst gold*	13	18.2	3.45	
Venezuela	*R. glaucus Benth*	7.5	13.05	3.1	García et al. (2003)
			%		
Brazil	*Rubus spp* cv. Brazos	7	1.74	2.88	Guedes et al. (2013)
	Rubus spp cv. Tupy	7.52	1.66	2.96	
Colombia	*R. alpinus* Macfad	8.18	1.81	2.77	Moreno-Medina and Deaquiz (2016)
	R. glaucus Benth	9.27	2.82	2.68	Rincón et al. (2015)
Peru	*R. fructicosus* L	10.55	0.93	3.4	Valencia and Guevara (2013)

TSS total soluble solids, *TTA* total titratable acidity (expressed as malic acid)

Table 2 Nutritional composition in fruits of the *Rubus* genus in 100 g of edible portion

Species	Producer country	% water	Energy (kcal)	Protein (g)	Total fat (g)	Carbohydrates (g)	Total fiber (g)	Ash (g)	Source
Rubus spp	Central America and Panama	88.15	43	1.39	0.49	9.61	5.3	6.37	Instituto de Nutrición de Centro América y Panamá INCAP (2012)
Rubus glaucus Benth. (without prickles)	Colombia	83.7	–	1	0.1	14.5	–	0.6	Garzón et al. (2015)
Rubus idaeus. L	Canada	85.75	52	1.2	0.65	11.94	6.5	–	Rao and Snyder (2010)
Rubus fructicosus L	Peru	82.98	66.43	0.93	0	13.19	2.48	0.42	Valencia and Guevara (2013)

Dietary patterns around the world suggest increasing the consumption of fruits and vegetables, as a sources of essential nutrients, fiber and some beneficial phytochemicals for health and reducing agents for chronic diseases (Seeram 2008). Table 2 and 3 show the nutritional composition of the fruits of different *Rubus* species and the importance in relation to other fruits, due to the high content of macro and micronutrients (calcium, potassium, phosphorus, magnesium, zinc, among others), and phytochemicals such as anthocyanins, tannins, flavonols, flavonoids and phenolic acids (Seeram 2006; Halvorsen et al. 2006). In addition to their striking colours ranging from red to purple or garnet, these fruits have a sweet acidified flavour, which exceeds 8–9 °Brix as reported by Rincon et al. (2015) for fruits of *R. alpinus* and *R. glaucus*. It is important to highlight that species such as raspberry (*Rubus idaeus*) contain ellagitannins and anthocyanins that differentiate them from other fruits (Rao and Snyder 2010), and it is precisely these type of characteristics that make berries foods with positive effects on the improvement and treatment of cardiovascular diseases, neurodegenerative diseases, some types of cancer (gastrointestinal), aging and obesity (Seeram 2008).

Rubus species are a source of nutrients including essential minerals, fatty acids, vitamins and different phytochemicals. Table 2 and 3 show nutrient profiles and mineral contents in raspberries and blackberries (*Rubus* spp, *Rubus glaucus* Benth (without prickles), *Rubus fructicosus, Rubus rosifolius, Rubus urticifolius, Rubus* spp Brazos, *Rubus* spp cv Tupy and *Rubus idaeus*), reported in different countries. These species have dietary fiber contents between 3.0 and 6.5 g 100 g^{-1} which aid in digestion (Bobinaité et al. 2016); they possess between 4 and 14 g of carbohydrates that intervene as a fast and profitable source of energy for the human body (Castellanos 2008). These berries contain a proportion of water close to 90% and less than 60 kcal which places them in a group of fruits that do not substantially intervene in the increase of body weight, as water is the vehicle or transport of different substances within the body.

Rubus fruits are also a good source of vitamin C (26.5 mg 100 g^{-1}), an essential vitamin that in low intake induces health problems, and even death (Lee and Kader 2000). Vitamin C content depends on agronomic management and postharvest management as reported by Miret and Munné-Bosch (2016), in raspberry cv. Heritage. Additionally, these fruits are recognized as a good source of thiamine, riboflavin, niacin, zinc, magnesium, potassium (150–200 mg 100 g^{-1}), phosphorus (10–40 mg), iron (0.5–1.5 mg 100 g^{-1}), calcium (25–40 mg 100 g^{-1}) and protein (1 g 100 g^{-1} on average), the basic components of living cells involved in the construction of antibodies, hormones, enzymes, neurotransmitters, and nutrient transporters among others (Buttriss 2000).

In *Rubus* species around the world, there is a great potential for the utilization of their natural compounds found in different parts of the plant as shown in Table 4, the former perhaps influenced by the great genetic variability that occurs within the species. In the case of fatty acids the species *R. glaucus* shows potential for the cosmetic and pharmaceutical industry for its contents of palmitic, stearic, oleic, linoleic and linoleic acid, and in addition, these type of berries are notable for having considerable amounts of polyphenols, represented in compounds such as anthocyanins (pelargonidin and cyanidin in the species of *R. idaeus*) and ellagitannins, which can be found in fruits, leaves and stems of some species of blackberries and raspberries. These benefits are not popularly recognized, since the majority of consumers only attribute medicinal and bioactive properties to the fruits. The antioxidant potential of the other parts of the plant includes concentration in leaves of the species *R. adenotrichos* and *R. coriifolius* (values higher than 1.8 µg EAG μL^{-1}) and in stems with values higher than 0.5 µg EAG μL^{-1} (Silva-Adame et al. 2013). At the same time there are other types of compounds such as triterpens in the aerial part of the plant, and glucans in roots. These compounds have important pharmaceutical uses for their antibacterial and immunological action (Wang et al. 2000; Weihua et al. 2009).

Fig. 4 reports investigations from various authors about how the increase in the consumption of fruit aids in prevention of diseases and reduction of stress, and lowers the risk of cardiovascular diseases and cancer (Trivedi et al. 2016; Law and Morris 1998). These positive effects are attributed to the presence of polyphenols (Van der Sluis et al. 2001; Silva-Adame et al. 2013). The total amount of secondary metabolites in plants depends on the agronomic management and environmental conditions where the crop is grown (Wang and Zheng 2001; Zheljazkov et al. 2009). *Rubus* species are used in traditional medicine for the management of diarrhea and the treatment of wounds and burns. The consumption of infusions of leaves can induce sedative effects, reduce kidney stones, and inhibit prostate and colon cancer. Additionally, these species are reported as useful plants in the recovery of natural resources in phytoremediation processes (Thinquino 1993; Wang and Lin

Table 3 Content of minerals and vitamins in *Rubus* species, in 100 gr of edible portion

Species Producer country		Calcium	Phosphorous	Iron	Thiamine	Riboflavin	Niacin	Vitamin C	Potassium	Zinc	Magnesium	Vitamin B6	Reference
		mg											
Rubus spp	Central America and Panama	29	22	0.62	0.02	0.03	0.65	21	162	0.53	20	0.03	Instituto de Nutrición de Centro América y Panamá INCAP (2012)
Rubus glaucus Benth (without prickles)	Colombia	42	10	1.7	–	–	–	–	–	–	–	–	Garzón and Gómez (2015)
Rubus idaeus L	Canada	25	29	0.69	0.032	0.038	0.598	26.2	151	0.4	22	0.055	Rao and Snyder (2010)
Rubus rosifolius Sm. var Rosifolius	Brazil	0.32	0.33	0.005	–	–	–	–	1.7	0	0.18	–	Ferreira and Bergman (2008)
Rubus urticifolius Poir		0.34	0.22	0.003	–	–	–	–	1.2	0	0.23	–	
Rubus spp. cv. Brazos	Brazil	14.3	17.8	3.66	–	–	–	–	124	0.2	16.3	–	Guedes et al. (2013)
Rubus spp cv. Tupy		11.6	19.9	1.32	–	–	–	–	125	0.2	15	–	

Table 4 Chemical composition in some *Rubus* species

Producer country	Plant part	Species	Quantity	Component	Source
			%		
Colombia	Seeds	*R. glaucus*	11.24	Palmitic acid	Cerón et al. (2012)
			4.11	Stearic acid	
			9.42	Oleic acid	
			50.10	Linoleic acid	
			25.10	Linolenic acid	
			mg 100 g^{-1}		
United States	Fruits	*R. ursinus* G4 Bulk	211	Total content of anthocyanins	Moyer et al. (2002)
		R. ursinus G4-19	206		
		R. niveus Thumb	230		
		R. occidentalis cv. Early sweet	464		
		R. occidentalis cv Munger	627		
Canada	Fruits	*R. idaeus*	25.4	Cyanidin-3-sophoroside	Kassim et al. (2009); Rao and Snyder (2010)
			7.2	Cyanidin-3-glucosylrutinoside	
			3.9	Cyanidin-3-glucoside	
			2.3	Cyanidin-rutinoside	
			0.06	Pelargonidin-3-sophoroside	
			0.1	Pelargonidin-3-glucosylrutinoside	
			0.12	Pelargonidin-3-glucoside	
			0.005	Pelargonidin-3-rutinoside	
United States	Fruits	*R. ursinus* G4 Bulk	678	Total phenols	Moyer et al. (2002)
		R. ursinus G4-19	629		
		R. niveus Thumb	402		
		R. occidentalis cv. Early sweet	897		
		R. occidentalis cv Munger	980		
Lithuania	Fruits	*R. idaeus. cv. Bristol*	715	Total phenols	Bobinaité et al. (2012)
Hungary	Fruits	*Rubus idaeus*	226	Total phenols	Lugasi. et al. (2011)
Finland	Fruits	*R. idaeus*	76	Ellagitannins (sanguiin H-6 76 29)	Koponen et al. (2007)
			31	Ellagitannins (lambertianin C 31 29)	
			0.11	Ellagitannins (ellagic acid)	
Japan	Leaves	*R. microphyllus* *R. koehneanus* *R. trifidus*	–	Esters and β-Glucosyl esters of 19α-hydroxyursolic acid derivatives	Takashi et al. (1984); Zhang et al. (2015)
			μg EAG μL^{-1}		
Mexico	Leaves	*R. adenotrichos*	1.87	Polyphenols	Silva-Adame et al. (2013)
	Stems	*R. adenotrichos*	0.454	Polyphenols	
	Leaves	*R. coriifolius*	3.608	Polyphenols	
	Stems	*R. coriifolius*	0.761	Polyphenols	
China	Aerial plant part	*R. pungens*	–	Saponin triterpenoid (rubupungenoside A and B)	Wang et al. (2000)

Table 4 (Continued)

Producer country	Plant part	Species	Quantity	Component	Source
China	Aerial plant part	*R. lambertianus*	–	Triterpens and glucosides	Shu-Feng et al. (2015)
China	Root	*R. crataegifolius* Bge	–	Glucans	Weihua et al. (2009)

EAG Equivalents of gallic acid (Silva-Adame et al. [2013])

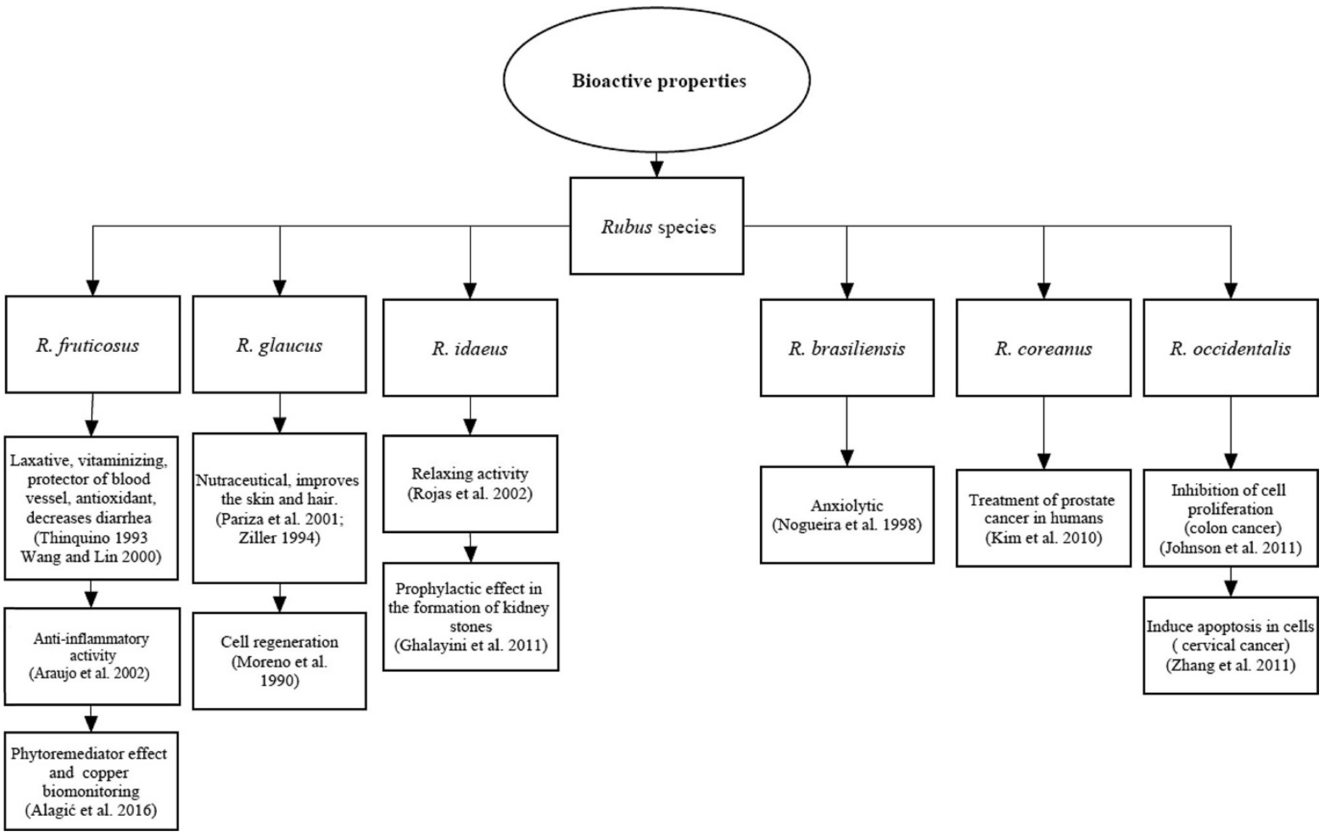

Fig. 4 Uses and bioactive properties in *Rubus* species

2000; Pariza et al. 2001; Ziller 1994; Moreno et al. 1990; Araujo et al. 2002; Rojas-Vera et al. 2002; Nogueiraa et al. 1998; Kim et al. 2010; Ghalayini et al. 2011; Alagić et al. 2016; Zhang et al. 2011). Fig. 4 shows the potential use of these species in different countries and their benefits to human health. Furthermore, the production and development of viable supply chains of blackberries and raspberries also contributes to increased income in rural communities.

Conclusions

There is a great potential for the use of various fruits of the *Rubus* species due to their high quantities of polyphenols, ellagitannins and anthocyanins, which provide an interesting source of natural antioxidants of vegetable origin. The nutritional benefits of the *Rubus* species include high dietary fiber and water content, an adequate supply of calories and a good source of vitamin C. The agroindustrial potential of the different species of this genus depends on the agroecological conditions and the agronomic management of the regions where the crops are grown. Additionally, plants of this species are an important source of nutrients and phytochemicals that can influence the prevention and control of diseases in humans.

Acknowledgements This work was supported by Colciencias and Gobernación de Boyacá, Call 733/2015.

Conflict of interest B.L. Moreno-Medina, F. Casierra-Posada and J. Cutler declare that they have no competing interests.

References

Agronet (2017) Estadísticas. http://www.agronet.gov.co/estadistica/Paginas/default.aspx. Accessed 9 Dec 2017

Alagić S, Stankov V, Mitić V, Cvetković J, Petrović G, Stojanović G (2016) Bioaccumulation of HMW PAHs in the roots of wild blackberry from the Bor region (Serbia): phytoremediation and biomonitoring aspects. Sci Total Environ 562:561–570. https://doi.org/10.1016/j.scitotenv.2016.04.063

Alice LA (2002) Evolutionary relationships in Rubus (Rosaceae) based on molecular data. Acta Hortic 585:79–83. https://doi.org/10.17660/ActaHortic2002.585.9

Alice LA, Campbell CS (1999) Phylogeny of Rubus (Rosaceae) based on nuclear ribosomal DNA internal transcribed spacer region sequences. Am J Bot 86:81–97

Araujo L, Buitrago D, Marquina M, Morales N, Méndez G, Pernía T, Sosa M (2002) Comparación de la actividad anti-inflamatoria de los polifenoles presentes en las frutas; Mora (Rubus fruticosus B.), Fresa (Fragaria vesca L.) y Grapefruit (Citrus paradasi M). Rev Fac Farm 44:64–69

Ayala LC, Valenzuela C, Bohórquez Y (2013) Caracterización fisicoquímica de mora de castilla (Rubus glaucus Benth) en seis estados de madurez. Biotecnol Sect Agropecu Agroind 11(2):10–18

Azcón-Bieto J, Talón M (2008) Fundamentos de Fisiología Vegetal. Interamericana-McGraw-Hill, Madrid

Ballington JR, Luteyn MM, Thompson K, Romoleroux K, Castillo R (1993) Rubus and Vacciniaceous germplasm resources in the Andes of Ecuador. Plant Genet Resour Newsl 93:9–15

Bérdy J (2005) Bioactive microbial metabolites. J Antibiot 58(1):1–26. https://doi.org/10.1038/ja.2005.1

Bobinaitė R, Viškelis P, Venskutonis R (2012) Variation of total phenolics, anthocyanins, ellagic acid and radical scavenging capacity in various raspberry (Rubus spp.) cultivars. Food Chem 132:1495–1501. https://doi.org/10.1016/j.foodchem.2011.11.137

Bobinaitė R, Viškelis P, Venskutonis R (2016) Chemical composition of raspberry (Rubus spp.) cultivars. In: Simmonds M, Preedy V (eds) Nutritional composition of fruits cultivars. Academic Press, San Diego https://doi.org/10.1016/B978-0-12-408117-8.00029-5

Bushway L, Pritts M, Handley D (2008) Raspberry & blackberry production guide. NRAES, Ithaca, New York

Buttriss J (2000) Nutrient requirements and optimization of intakes. Brit Med Bull 56(1):18–33

Cancino O, Sanchez L, Quevedo E, Díaz C (2011) Caracterización fenotípica de accesiones de especies de Rubus L. de los municipios de Pamplona y Chitagá, Región Nororiental de Colombia. Univ Sci 16(3):219–233

Castellanos E (2008) La nutrición, su relación con la respuesta inmunitaria y el estrés oxidativo. Rev Habanera Cien Med 7(4):1–12

Cerón A, Osorio O, Hurtado A (2012) Identificación de ácidos grasos contenidos en los aceites extraídos a partir de semillas de tres diferentes especies de frutas. Acta Agron 61(2):126–132

FAO (Food and Agriculture Organization) (2017) Faostat. http://www.fao.org/faostat/es/#data/QC. Accessed 9 Dec 2017

Ferreira V, Bergman I (2008) Teores de proteína e minerais de espécies nativas, potenciais hortaliças e frutas. Cien Tecnol Alime 28(4):846–857

Gandhi S, Mahajan V, Bedi Y (2015) Changing trends in biotechnology of secondary metabolism in medicinal and aromatic plants. Planta 241(2):303–317. https://doi.org/10.1007/s00425-014-2232-x

García D (2004) Los metabolitos secundarios de las especies vegetales. Pasto Forraj 27(1):1–12

García D, Viloria-Matos A, Belén D, Moreno-Álvarez M (2003) Características físico-químicas y composición de ácidos grasos del aceite crudo extraído de residuos de mora (Rubus glaucus Benth). Grasa Aceit 54(3):259–263

Garzón L, Gómez C (2015) Caracterización bromatológica y microbiológica de cultivos de la mora de castilla sin espinas (Rubus glaucus Benth) del corregimiento de la Bella y del municipio de Santa Rosa de Cabal (Risaralda, Colombia). Universidad Tecnológica de Pereira, Colombia

Gershenzon J, Dudareva N (2007) The function of terpene natural products in the natural world. Nat Chem Biol 3:408–414. https://doi.org/10.1038/nchembio.2007.5

Ghalayini IF, Al-Ghazo MA, Harfeil MN (2011) Prophylaxis and therapeutic effects of raspberry (Rubus idaeus) on renal stone formation. Int Braz J Urol 37:259–266

Grajales-Conesa J, Meléndez-Ramírez V, Cruz-López L (2011) Aromas florales y su interacción con los insectos polinizadores. Rev Mex Biodivers 82(4):1356–1367

Guedes M, Abreu C, Maro L, Pio R, Abreu J, Oliveira J (2013) Chemical characterization and mineral levels in the fruits of blackberry cultivars grown in a tropical climate at an elevation. Acta Sci Agron 35(2):191–196. https://doi.org/10.4025/actasciagron.v35i2.16630

Gómez-Romero M, Segura-Carretero A, Fernández-Gutiérrez A (2010) Metabolite profiling and quantification of phenolic compounds in methanol extracts of tomato fruit. Phytochemistry 71(16):1848–1864. https://doi.org/10.1016/j.phytochem.2010.08.002

Halvorsen BL, Carlsen MH, Phillips KM, Boehn SK, Holte K, Jacobs DR, Blomhoff R (2006) Content of redox-active compounds (ie, antioxidants) in foods consumed in the United States. Am J Clin Nutr 84:95–135

Hernández M (2004) Recomendaciones nutricionales para el ser humano: actualización. Rev Cuba Investig Biomed 3(4):266–292

Instituto de Nutrición de Centro América y Panamá INCAP (2012) Tabla de composición de alimentos de Centroamérica, 2nd edn. Serviprensa, Guatemala

Johnson JL, Bomser JA, Scheerens JC, Giusti MM (2011) Effect of black raspberry (Rubus occidentalis L.) extract variation conditioned by cultivar, production site, and fruit maturity stage on colon cancer cell proliferation. J Agric Food Chem 59:1638–1645. https://doi.org/10.1021/jf1023388

Kalkman C (2004) Rosaceae. In: Kibitzki k (ed) The families and genera of vascular plants, vol IV. Springer, Berlin, Heidelberg, New York., pp 343–386

Kassim A, Poette J, Paterson A, Zait D, McCallum S, Woodhead M, Smith K, Hackett C, Graham J (2009) Environmental and seasonal influences on red raspberry anthocyanin antioxidant contents and identification of quantitative traits loci (QTL). Mol Nutr Food Res 53:625–634. https://doi.org/10.1002/mnfr.200800174

Kim JE, Kwon JY, Seo SK, Son JE, Jung SK, Min SY, Hwang MK, Heo YS, Lee KW, Lee HJ (2010) Cyanidin suppresses ultraviolet B-induced COX-2 expression in epidermal cells by targeting MKK4, MEK1, and Raf-1. Biochem Pharmacol 79:1473–1482. https://doi.org/10.1016/j.bcp.2010.01.008

Koponen JM, Happonen AM, Mattila PH, Torronen AR (2007) Contents of anthocyanins and ellagitannins in selected foods consumed in Finland. J Agric Food Chem 55:1612–1619

Law MR, Morris JK (1998) By how much does fruit and vegetable consumption reduce the risk of ischaemic heart disease? Eur J Clin Nutr 52:549–556

Lee S, Kader A (2000) Preharvest and postharvest factors influencing vitamin C content of horticultural crops. Postharvest Biol Technol 20(3):207–220. https://doi.org/10.1016/S0925-5214(00)00133-2

Lugasi A, Hovari J, Kadar G, Denes S (2011) Phenolics in raspberry, blackberry and currant cultivars grown in Hungary. Acta Aliment Hung 40:52–64. https://doi.org/10.1556/AAlim.40.2011.1.8

Markakis P (1982) Anthocyanins as food colors. Academic Press, New York

Miret J, Munné-Bosch S (2016) Abscisic acid and pyrabactin improve vitamin C contents in raspberries. Food Chem 203:216–223. https://doi.org/10.1016/j.foodchem.2016.02.046

Moraes M, Mostacedo B, Zapata B, Altamirano S (2009) Libro rojo de parientes silvestres de cultivos de Bolivia. Plural Editores, La Paz
Moreno J, Bueno J, Navas J, Camacho F (1990) Tratamiento de las ulceras cutáneas con aceite de rosa mosqueta. Med Cutan Ibero Lat Am 18(1):63–66
Moreno-Medina BL, Deaquiz Y (2016) Caracterización de parámetros fisicoquímicos en frutos de mora (Rubus alpinus Macfad). Acta Agron 65(2):130–136. https://doi.org/10.15446/acag.v65n2.45587
Moyer R, Hummer K, Finn C, Frei B, Wrolstad R (2002) Anthocyanins, Phenolics, and antioxidant Capacity in Diverse Small Fruits: Vaccinium, Rubus, and Ribes. J Agric Food Chem 50(3):519–525. https://doi.org/10.1021/jf011062r
Nogueiraa E, Rosab G, Vassilieffa V (1998) Involvement of GABA A-benzodiazepine receptor in the anxiolytic effect induced by hexanic fraction of Rubus brasiliensis. J Ethnopharmacol 61(2):119–126. https://doi.org/10.1016/S0378-8741(98)00023-3
Pariza MW, Park Y, Cook ME (2001) The biologically active isomers of conjugated linoleic acid. Prog Lipid Res 40(4):283–298. https://doi.org/10.1016/S0163-7827(01)00008-X
Rao V, Snyder D (2010) Raspberries and human health: a review. J Agric Food Chem 58(7):3871–3883. https://doi.org/10.1021/jf903484g
Rincón C, Moreno-Medina BL, Deaquiz Y (2015) Parámetros poscosecha en dos materiales de mora (Rubus Glaucus Benth y Rubus Alpinus Macfad). Cult Cient 13:16–25
Rojas-Vera J, Patel A, Dacke C (2002) Relaxant activity of raspberry (Rubus idaeus) leaf extract in guinea-pig ileum in vitro. Phytother Res 16(7):665–668. https://doi.org/10.1002/ptr.1040
Rotundo A, Bounous S, Benvenuti G, Vampa M, Melegari, Soragni F (1998) Quality and yield of Ribes and Rubus cultivars grown in southern Italy hilly locations. Phytother Res 12:135–137
Seeram NP (2006) Bioactive polyphenols from foods and dietary supplements: challenges and opportunities. In: Wang M, Sang S, Hwang LS, Ho Chi-Tang (eds) Herbs: challenges in Chemistry and Biology. American Chemical Society https://doi.org/10.1021/bk-2006-0925
Seeram NP (2008) Berry Fruits: Compositional elements, biochemical activities, and the impact of their intake on human health, performance, and disease. J Agric Food Chem 56(3):627–629. https://doi.org/10.1021/jf071988k
Sepúlveda J, Porta D, Rocha S (2003) La participación de los metabolitos secundarios en la defensa de las plantas. Rev Mex Fitopatol 21(3):355–363
Shu-Feng T, Hui-Jun Z, Jian-Guang L, Ling-Yi K (2015) Triterpenes and triterpene glucosides with their oxidative stress injury protective activity from Rubus lambertianus. Phytochem Lett 12:1–5. https://doi.org/10.1016/j.phytol.2015.02.001
Silva-Adame M, Pedraza-Arriola L, Garcia-Saucedo P (2013) Zarzamoras silvestres: Plantas mexicanas con potencial antimicrobiano. Memorias X encuentro de la mujer en la ciencia, México, 15.05-17.05.2013. pp 1–5. http://congresos.cio.mx/memorias_congreso_mujer/archivos/extensos/sesion5/S5-BCA19.pdf. Accessed 9 Dec 2017
Taiz L, Zeiger E (2010) Plant physiology, 5th edn. Sinauer Associates, Sunderland
Takashi S, Takashi T, Osamu T, Naohiro N (1984) β-Glucosyl esters of 19α-hydroxyursolic acid derivatives in leaves of Rubus species. Phytochemistry 23(12):2829–2834. https://doi.org/10.1016/0031-9422(84)83023-X
Thinquino B (1993) Terapias Naturales. Publicaciones Latinoamericanas Rayos de Luz, Bogotá
Trivedi A, Vermaa SK, Tyagi RK (2016) Variability in morpho-physiological traits and antioxidant potential of Rubus species in Central Himalayan Region. Ind Crops Prod 82:1–8. https://doi.org/10.1016/j.indcrop.2015.12.022
Valencia C, Guevara A (2013) Elaboración de néctar de zarzamora (Rubus fructicosus L.). Sci Agropecu 4(2):101–109. https://doi.org/10.17268/sci.agropecu.2013.02.03
Van der Sluis AA, Dekker M, De Jager A, Jongen WM (2001) Activity and concentration of polyphenolic antioxidants in apple: effects of cultivar, harvest year, and storage conditions. J Agric Food Chem 49:3606–3613
Wang SY, Lin HS (2000) Antioxidant activity in fruits and leaves of blackberry, raspberry, and strawberry varies with cultivar and developmental stage. J Agric Food Chem 48(2):140–146
Wang SY, Zheng W (2001) Effect of plant growth temperature on antioxidant capacity in strawberry. J Agric Food Chem 49(10):4977–4982
Wang B-G, Zhu W-M, Li X-M, Jia Z-J, Hao X-J (2000) Rubupungenosides A and B, two novel triterpenoid saponin dimers from the aerial parts of Rubus pungens. J Nat Prod 63:851–854. https://doi.org/10.1021/np990473n
Weihua N, Zhang X, Hongtao B, Jeff I, Li J, Chengxin S, Jinbo F, Guihua T, Yifa Z, Jimin Z (2009) Preparation of a glucan from the roots of Rubus crataegifolius Bge. and its immunological activity. Carbohydr Res. https://doi.org/10.1016/j.carres.2009.08.042
Zhang TT, Lu CL, Jiang JG, Wang M, Wang DM, Zhu W (2015) Bioactivities and extraction optimization of crude polysaccharides from the fruits and leaves of Rubus chingii Hu. Carbohydr Polym 130:307–315. https://doi.org/10.1016/j.carbpol.2015.05.012
Zhang Z, Knobloch TJ, Seamon LG, Stoner GD, Cohn DE, Paskett ED, Fowler JM, Weghorst CM (2011) A black raspberry extract inhibits proliferation and regulates apoptosis in cervical cancer cells. Gynecol Oncol 123(2):401–406. https://doi.org/10.1016/j.ygyno.2011.07.023
Zheljazkov VD, Cerven V, Cantrell CL, Ebelhar WM, Horgan T (2009) Effect of nitrogen, location and harvesting stage on peppermint productivity, oil content, and oil composition. Hortic Sci 44(5):1267–1270
Ziller S (1994) Grasas y aceites alimentarios, 7th edn. Ed. Acribia, Zaragoza

Brigitte Liliana Moreno-Medina was born on 08/27/1983 in Tunja, Colombia. She holds a Bachelor in Agronomy (2007) and Master in Plant Physiology (2014), and graduated from the Universidad Pedagógica y Tecnológica de Colombia (UPTC). She is currently a candidate for a PhD in Chemistry at the UPTC. Between 2007 and 2014 she worked as a technical assistant in cold and medium climate crops (fruit trees, vegetables and ornamentals), and as a lecturer of physiology and plant reproduction in different university institutions.