Main characteristics of peanut skin and its role for the preservation of meat products

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Abstract

Background: The produced peanuts by-products are a huge challenge, but it is recognized to be a source of valuable nutrients, including natural antioxidants and antimicrobials. Antioxidants are considered as necessary ingredients in food to prevent oxidative reactions and their undesirable effects in food quality during processing and storage. However, the use of such compounds is regulated due to their harmful effects revealed by *in vitro* and *in vivo* studies. The use of natural antioxidants appears as an interesting alternative for food producers, particularly meat industries.

Scope and approach: Peanut skin (PS), a by-product of peanut processing in agro-industries, constitutes an under-explored source of natural antioxidants. Thus, this review kills to birds with one stone and addresses both the reuse of peanuts by-products and societal health, reducing the use of synthetic antioxidants and antimicrobials.

Key findings and conclusions: Proanthocyanidins are the main compounds in PS that are associated with the antioxidant activity *in vitro* and its protective effect in meat products. Studies in recent literature strengthen the role of PS as a natural source of antioxidants wherein oxidative reactions involving mainly pigments, lipids and proteins are delayed.

Keywords: Proanthocyanidins, Phenolic compounds, Lipid oxidation, Loss of quality; Oxidative reactions, Antioxidant activity

1. Introduction

The concepts and goals involved in production of meat and meat products have been evolving during the last decades partially due to growing knowledge of consumers about the relationship between food composition and health. General quality and safety became expected characteristics while the preference for natural additives instead of chemical ones, the perception of potential harmful effects of chemical additives and the general health interest gained more importance in purchase intention of meat and meat products (Jayasena & Jo, 2013; Hung, de Kok & Verbeke, 2016).

To attend consumer's expectations regarding healthy aspects, food manufacturers, producers and researchers are constantly searching for natural alternatives to synthetic additives. One of the main food additives involved in this context are the antioxidants, which are widely used in food industry to delay oxidative reactions during processing and storage. However, the consumption of synthetic antioxidants such as butylated hydroxytoluene and butylated hydroxyanisole (BHT and BHA, respectively) is suggested to be limited due to harmful effects reported in several *in vitro* and *in vivo* studies (EFSA, 2011; EFSA, 2012).

In this context, the replace of synthetic antioxidants by natural compounds is considered as a main strategy to prevent lipid oxidation of meat products. The group of phenolic compounds, naturally present in plant tissue and widely distributed in nature, plays a central role in this strategy. Beverages, vegetables, fruits and legumes are main sources in the human diet (Shahidi & Ambigaipalan, 2015). However, residues from agro-industry rich in phenolic compounds are discarded worldwide and thus, a relevant amount of natural

antioxidants that could be used as high added value products is lost (Moure et al., 2001).

Peanut skin (PS) is the nontoxic pink-red layer that covers peanuts and is the primary residue of peanut processing which represents less than 3% of peanut weight. This by-product has limited applications in industry due to its low commercial value. In addition, the use of PS in animal feed is limited to a minor component due to the high content of tannins and low calorie level (Francisco & Resurreccion, 2009; Sobolev & Cole, 2004). However, PS is a major source of phenolic compounds, particularly proanthocyanidins, among peanut constituents (skin, hull and kernel) (Win et al., 2011). In folk medicine, PS is commonly used in China to treat hemorrhage and bronchitis (Lou et al., 1999). Due to the potential use of peanut skin as natural antioxidant, this review provides an overview of the studies regarding the phenolic composition, antioxidant and anti-microbial potential of peanut skin and their effects in ground meat and meat products.

2. Oxidative reactions and quality loss in meat and meat products

The quality of meat and meat products decays during storage. Microbiological growth and oxidative reactions play a central role in meat and muscle products deterioration resulting in unacceptable products from a sensory and microbiological point of view. The microbial growth in meat leads to visual perception of slime and colonies, discoloration (reducing of redness), formation and accumulation off-flavors and off-odors, gas production (microbial metabolism) and pH decrease (Borch, Kant-Muermans & Blixt, 1996; Gram et al., 2002).

On the other hand, oxidative reactions degrade lipids and proteins due to formation of free radicals (high reactivity intermediate compounds). The reduction/loss of characteristic cherry-red color, accumulation of volatile and non-volatile compounds that confers rancid odor and off-flavor, loss of protein and lipid stability and functionality, reduction in nutritive value and accumulation of compounds with potential harmful effect have been related to oxidative reactions in lipids and proteins (Falowo, Fayemi & Muchenje, 2014).

In lipid oxidation, the first stage is known as *initiation* and is characterized by the formation of alkyl free radical due to reaction of unsaturated fatty acid with oxygen radicals and transition metals. In the second stage (*propagation*), alkyl radicals react with triplet oxygen and generate peroxy radicals. These radicals are highly reactive and abstract hydrogen atoms from unsaturated fatty acids that form hydroperoxides and new alkyl free radicals. The production of new alkyl radicals is the center of propagation stage and disseminates the oxidation of unsaturated fatty acids with an increasing rate. Finally, the *termination* is the last stage of lipid oxidation wherein radicals form non-radical products that are more stable than free radicals involved in the *propagation* stage (Berton-Carabin, Ropers & Genot, 2014).

The progress of lipid oxidation, particularly due to decomposition of hydroperoxides, can lead to remarkable changes in flavor of meat and meat products. The hydroperoxide decomposition forms several compounds such as aldehydes that contribute, in some extension, to characteristic flavor of meat and meat products. However, the accumulation of such compounds can be sensorially perceived as undesirable rancidity (Frankel, 1991). So, the follow up of volatile compounds accumulation have been commonly used to evaluate the

oxidative stability of meat and meat products. Aldehydes are the main compounds involved in this context due to fast increase of both total aldehyde and individual compounds (e.g. heptanal and hexanal) content in meat products (Shahidi & Pegg, 1994; Ross & Smith, 2006; Jayasena & Jo, 2014).

Similarly to flavor, color is an important attribute in meat and meat products particularly related to freshness perception by consumers. The characteristic color of fresh meat is attributed to myoglobin. Depending on the iron oxidative state and ligands in the center of the molecule, myoglobin can be found in one of the following three main states: deoxymyoglobin, oxymyoglobin and metmyoglobin. Myoglobin is denominated deoxymyoglobin when iron is in ferrous (+2) form, which renders a purplish-red color. The oxymyoglobin pigment (cherry-red color) is formed due to deoxymyoglobin exposure to atmospheric oxygen wherein ferrous form is maintained and O₂ became the ligand. In favorable conditions to iron oxidation, both deoxymyoglobin and oxymyoglobin pigments are converted to metmyoglobin that has iron in ferric (+3) form and contains water as ligand. Once metmyoglobin is formed, meat and meat products acquire a brownish-red color (Faustman, 1990).

These heme pigments can influence and can be influenced by lipid and protein oxidation. Color deterioration can be induced by lipid oxidation due to generation of primary and secondary products formed in lipid peroxidation such as aldehydes that oxidize oxymyoglobin, enhance the pro-oxidant activity of metmyoglobin and also impair the enzymatic reduction of metmyoglobin (Faustman, 1990; Min & Ahn, 2005). On the other side, the oxidation of oxymyoglobin form superoxide anion that is converted in hydrogen peroxide and reacts with metmyoglobin forming a complex named ferryl myoglobin. In

addition, the release of iron from heme pigments is also a suggested mechanism involved in lipid peroxidation (Faustman et al., 2010).

Protein oxidation in meat involves complex reactions that are influenced by the type of amino acid and side chain, the initiation of oxidative reactions in proteins and protein structure. In these reactions, proteins undergo covalent modifications due to either activity of reactive species or reaction to secondary products from oxidative reactions. In early stages of protein oxidation, some amino acids may be firstly oxidized such as cysteines and methionine (due to presence of sulfur centers that are prone attacked by reactive oxygen species) and tryptophan (susceptible to transition metals) (Lund et al., 2011). These and other amino acids may undergo the process known as carbonylation wherein carbonyl proteins such as α -amino adipic and γ -glutamic semi-aldehydes are usually measured. The progress of protein oxidation may influence the functionality of proteins (due to aggregation, denaturation and cross-linking formation), nutritional value (loss of essential amino acids) and sensory attributes such as texture (cross-linking formation, reduction in juiciness and increasing of hardness) and flavor (formation of Strecker aldehydes) in meat and derived products (Estévez, 2011; Soladoye et al., 2015).

3. PS phenolic compounds and antioxidant activity

The extraction of natural antioxidants from PS requires optimized conditions to maximize the extraction of phenolic compounds wherein many variables are involved (**Table 1**).

Peanut variety, pre-treatments (for skin removal or microbial count reduction), solvent (pure or mixture), number of sequential extractions,

PS/solvent ratio and time of extraction are considered important factors that influence the phenolic content of PS extract (PSE).

Like in many other natural extracts, the characterization of mechanisms involved in PSE antioxidant activity is a challenging task and requires more than one method. This consideration is due to the characteristics of each antioxidant assay that have a specific mechanism, solvent, interaction between natural active compounds and reagents and reaction time which does not allow direct comparisons among methods. In relation to antioxidant mechanisms, methods can be separated in the following categories: radical scavenging, reducing power, lipid peroxidation inhibition and antioxidant methods (Carocho & Ferreira, 2013; Alam, Bristi & Rafiquzzaman, 2013).

Among the radical scavenging assays, DPPH radical assay (2,2-Diphenyl-1-picrylhydrazyl) is the most common test used in the evaluation of PSE and isolated compounds from PS (Lou et al., 2004; Wang et al., 2007; Chukwumah et al., 2009; Win et al., 2011; de Camargo et al., 2012; Braga et al., 2016) which can be attributed to its reduced cost in comparison to most methods and the simplicity and short required times (Alam, Bristi & Rafiquzzaman, 2013). Less common assays such as hydrogen peroxide (de Camargo et al., 2015), hydroxyl radical (Hoang et al., 2008; Yen et al., 2005) and superoxide anion radical (Hoang et al., 2008; Larrauri et al., 2016) scavenging assays have been used to evaluate the antioxidant activity of PSE.

Among the antioxidant assays, the ABTS radical assay is commonly used in PSE antioxidant evaluation, since this assay can measure the radical scavenging capacity of both hydrophilic and hydrophobic natural antioxidants (Yu, Ahmedna and Goktepe, 2005; de Camargo et al., 2015, de Camargo et al.,

2012). Similarly, a test that have gained more attention in recent years is the oxygen radical antioxidant capacity (ORAC) assay due to the possibility to quantify the antioxidant potential of both hydrophilic and hydrophobic natural antioxidants. This assay was applied in the study performed by Davis et al. (2010) wherein authors reported higher values for both hydrophilic (209,710 μ moles Trolox/100 g) and hydrophobic (6,320 μ moles Trolox/100 g) ORAC assays.

The ferric reducing antioxidant power (FRAP) assay is also reported for evaluation of PSE (Shem-Tov et al., 2012). Although few studies used FRAP assay to evaluate PS reducing power, this method is easily and rapidly performed, and requires few equipment and materials (Badarinath et al., 2010). Regarding the lipid peroxidation methods, de Camargo et al. (2015) applied the ferric thiocyanate assay to evaluate the effect of gamma-irradiation on decontamination of PS and Hoang et al. (2008) used this method to compare the antioxidant activity of PS removed from conventional and high-oleic peanuts. In addition, other assays that evaluate the capacity to interact and reduce the activity of potential catalyzers such as iron (Yen et al., 2005; Wang et al., 2007; Larrauri et al., 2016).

The skin removal from peanut kernel is one of the primary steps in peanut processing and affects the phenolic content of PS but conflicting information is reported in literature. Yu, Ahmedna and Goktepe (2005) observed that roasting of peanuts increased the phenolic content of PSE in comparison to direct peeling and blanching followed by peeling procedures, regardless the solvent applied.

In another study, Yu et al. (2006) assessed the effect of same PS removal techniques (direct peeling, peeling after blanching and peeling after roasting) and the number of successive extractions on the phenolic content of PSE. Authors observed a drastic reduction in phenolic content during the three sequential extractions. When extracts were combined, direct peeling and roasting treatments contained more phenolic compounds than PS subjected to blanching and then peeled (130.8 and 124.3 vs 15.1, respectively). In addition, authors also observed that all techniques for skin removal provided extracts with higher or similar antioxidant activity than Trolox (a water soluble analogue to vitamin E) and vitamin C. Differently, Larrauri et al. (2016) observed that blanching increased the extraction of phenolic compounds from PSE in comparison to roasting in crude extract (672.40 and 416.92 mg GAE/g, respectively) and water fraction (558.96 and 295.06 mg GAE/g, respectively) and ethyl acetate fraction (716.14 and 673.84 mg GAE/g, respectively) obtained from crude extract.

The effect of gamma irradiation on PS phenolic composition was studied by de Camargo et al. (2015) who observed that treatments with doses of 2.5 and 5 kGy increased the free phenolic content, proanthocyanidin content in this fraction and antioxidant potential. These irradiation treatments also reduced the yeasts, mold and coliform contamination in PS. However, authors reported that esterified phenolic content and its proanthocyanidin fraction and antioxidant potential. Interesting, PSE usually displays dark-red color (O'Keefe & Wang, 2006) but the main compounds involved in antioxidant activity are colorless.

The total phenolic, flavonoid and anthocyanin contents and antioxidant activity of 26 lines (Runner, Spanish, Valencia, Virginia and a combination of

theses varieties) were assessed, with large variations reported on phenolic (between 5 and 156 mg catechin/g), flavonoid (in the range of 5-140 mg catechin/g) and anthocyanin (from 0.6 to 127 mg cyanidin-3-glucoside/L) contents (Shem-Tov et al., 2012). The antioxidant activity, assessed by FRAP assay, (between 1.3 and 52 mM Trolox/100 g) was associated positively with phenolic ($r = 0.83$) and flavonoid ($r = 0.81$) content. In addition, authors also stated that PS color did not correlate with antioxidant activity, indicating that colorless phenolic compounds were the main agents involved in antioxidant activity of PS.

The phenolic composition of PS is largely composed by proanthocyanidins (oligomers and polymers of flavan-3-ols monomeric units) that are considered as the main antioxidant compounds in PS (Fig. 1). The degree of polymerization of proanthocyanidins in PS ranges from dimers to nonamers with several structures due to the variability in the combination of interflavan linkage: B-type with C4–C8 or C4–C6 bonds and A-type with C4–C8 or C4–C6 bonds and an extra C2–O–C7 bond. Recently, new proanthocyanidin derived compounds were reported: monomers and dimers linked to luteolin or kaempferol (Ma et al., 2014; Sarnoski et al., 2012). Proanthocyanidins are considered as the second most abundant class of polyphenols in diet, particularly due to consumption of chocolate, wine and peanuts with skin (Appeldoorn et al., 2009).

Other reported phenolic compounds were phenolic acids like *p*-coumaric acid, quinic acid, gallic acid, caffeic acid and protocatechuic acid; stilbenes (resveratrol), flavonoids (e.g. luteolin and quercetin) and their derived compounds like resveratrol-3-O-*p*-coumaroyltartaric acid, quercetin-3-O-[2-O- β -xylopyranosyl-6-O- α -rhamnopyranosyl]- β -glucopyranoside, epigallocatechin

gallate and quercetin methyl ether. Additionally, protocatechuic acid and *p*-coumaroyl derivatives (e.g., *p*-coumaroylferuloyltartaric acid, *p*-coumaroyl-O-pentoside and *p*-coumaroylcaffeoyltartaric acid) are considered as major non-proanthocyanidin phenolic compounds in PS (Larrauri et al., 2016; Ma et al., 2014; Francisco & Resurreccion, 2009; Lou et al., 2001).

The separation of proanthocyanidins from PS is a challenge task and requires the combination of multiple techniques to evaluate the molecular diversity of compounds. Appeldoorn et al. (2009) evaluated A-type proanthocyanidins (monomers to pentamers) by the combination of normal-phase and reversed-phase HPLC-MS analysis. A previous purification of monomers to pentamers proanthocyanidins was performed in normal-phase before the reversed-phase mode and indicated that around 95% of PS was composed by A-type proanthocyanidins. Another strategy is the fractionation by size exclusion that successfully separated proanthocyanidins from PS crude extract. The evaluation of molecular interflavan of a large number of oligomer and polymers (up to 5 units of flavan-3-ols) can be performed and allowed the elucidation of new structures (Sarnoski et al., 2012).

Recently, a bioassay-guided fractionation approach was used to evaluate the PS phenolic composition and to identify and elucidate the structure of its bioactive phenolic compounds (Oldoni et al., 2016). The comparison between proanthocyanidin A1 and proanthocyanidin A2 revealed that A1 dimer displayed higher antioxidant potential than A2 dimer in DPPH radical scavenging and Fe³⁺–TPTZ complex assay.

4. Extraction of antioxidant compounds from PS

Up to now, many conventional techniques have been applied to extract bioactive compounds from PS wherein many factors can influence the PSE phenolic content and its antioxidant activity. Nepote, Grosso and Guzmán (2002) observed that methanol and ethanol increased the extraction of phenolic compounds in defatted and non-defatted PS, while acetone displayed similar efficiency only in non-defatted PS. These authors also stated that phenolic content in PSE obtained with water was lower than observed for other solvents.

In another study, Nepote, Grosso and Guzmán (2005) assessed the effect of ethanol concentration in solvent (0-96%), PS size (0-10 mm and non-crushed skins), solvent/PS ratio (20-60 mL/g), time of extraction (0-120 min) and number of sequential extractions on the PSE phenolic content. Authors observed that the higher phenolic content was achieved using non-crushed peanut skins, 70% ethanol solution, solvent/PS ratio of 20 mL/g, 10 min of shaking and three sequential extractions. Similarly, Yu, Ahmedna and Goktepe (2005) assessed the effect of solvent composition (hot water, 80% methanol and 80% ethanol) in the extraction of antioxidant compounds from PS. According to authors, water was the less effective solvent for extraction of phenolic compounds while 80% methanol and 80% ethanol produced PSEs enhanced in both phenolic content and antioxidant activity of PSE.

There has been a need in recent years to develop more efficient processes, mainly due to environmental and economic implications, based on the green extraction concept (Chemat, Vian, & Cravotto, 2012; Rombaut, Tixier, Bily, & Chemat, 2014). The main goal was to avoid or reduce the use of organic solvents in extraction processes, but also considering other benefits like the a

reduced treatment time, improved mass transfer and increased extraction yields, while keeping a high extract quality, and low energy consumption.

So, a wide variety of non-conventional procedures such as ultrasound, microwave, electrotechnologies, negative pressure, high pressure, supercritical fluid extraction, have been used for the extraction of high-added value compounds from plant materials, wastes and by-products (Barba, Zhu, Koubaa, Sant'Ana, & Orlie, 2016; Barba, Terefe, Buckow, Knorr, & Orlie, 2015; Barba, Parniakov, et al., 2015; Galanakis, 2012, 2013; Koubaa et al., 2016; Puértolas & Barba, 2016; Roohinejad et al., 2016) (**Fig. 2**).

For instance, Liu et al. (2011) evaluated the effect of ultrasonic power (120-270 W), temperature (20-70 °C), time (5-55 min), PS/solvent ratio (1:10-1:35) and ethanol concentration (30-80%) in an orthogonal test. The authors stated that PS/solvent ratio was the most important factor, followed by ultrasonic power, time and temperature, while the ethanol content was the less important. The highest proanthocyanidin content was obtained when PS/solvent ratio was set at 1:24; ultrasonic power set to 120 W; extraction time and temperature set to 5 min and 35 °C, respectively; and aqueous solvent with 55% of ethanol.

In the study performed by Ballard et al (2010), the effect of microwave-assisted extraction on the phenolic antioxidant potential of PSE was studied. The authors assessed the effect of microwave power (10-90%), time of extraction (30-150 s) and PS mass (1.5-3.5 g) with 37.5 mL of 30% ethanol (EtOH) in water. According to authors, the highest phenolic content was obtained with 1.5 g of skins subjected to 30 s of irradiation time at 90% of

microwave power. However, to obtain the maximum antioxidant activity a longer time was required: 150 s with the same microwave power and PS mass.

Recently, Bodoira et al. (2017) extracted phenolic compounds using the sub-critical water extraction technique. The authors stated that the highest recovery of phenolic compounds (mainly procyanidin and proanthocyanidin) was obtained with solvent flow of 7 g/mL (60.5% ethanol as co-solvent) at 220 °C. The PSE obtained from this optimized condition displayed higher antioxidant activity than BHT.

5. Antimicrobial potential of PS

Although phenolic compounds are known for their role in the prevention of oxidative reactions, these compounds have also been investigated for their antimicrobial activity (Cueva et al., 2010; Daglia, 2012; Lucchini, Corre, & Cremieux, 1990; Proestos, Boziaris, Nychas, & Komaitis, 2006; Rodríguez Vaquero, Alberto, & de Nadra, 2007; Wen, Delaquis, Stanich, & Toivonen, 2003). Generally, phenolic compounds have been reported to present properties varying from inhibitory to microbiocide (Lucchini et al., 1990). These activities have been observed against Gram-positive, Gram-negative, yeasts and fungi, even though contradictory findings have been reported (Alves et al., 2013; Maddox, Laur, & Tian, 2010; Wen et al., 2003). Part of these discrepancies regarding the antimicrobial activity of phenolic compounds can be associated to the analytical approach for *in vitro* testing, such as solubilization of phenolic compounds, interactions with the substrate, among others (Wen et al., 2003). Besides, the antimicrobial effects can be associated to the impact of composition of phenolic compounds tested. Therefore, the source from which the phenolic compounds are obtained, the extraction method and the

composition of extract comprise key factors for further applications. Currently, De Camargo et al. (2017) assessed the anti-microbial potential of PS. This study has assessed the antimicrobial properties of PS or its fractions against several foodborne microorganisms, including bacteria, yeasts and moulds. A limitation is that only *in vitro* assessment was performed and it is known that substrate composition affects the antimicrobial activity of natural compounds (Aziz & Karboune, 2017; Lucera, Costa, Conte, & Del Nobile, 2012). Despite this, *in vitro* assessment of the antimicrobial activity of PS is important because it allows the association between PS fraction, its composition and antimicrobial activities. This analysis should include an evaluation of the effectiveness of the compounds or extracts against yeast, moulds, Gram-positive and Gram-negative bacteria. Once a relation between composition of PS specific compounds or extracts and their antimicrobial (inhibitory or microbiocidal) activities is determined, testing taking into account the microbiota of specific meat products can be conducted. This determination will be key to to allow the application of PS phenolic compounds aiming to extend the shelf-life and to guarantee food safety of meat products.

6. PS in meat and meat products

The information about the effect of PS in animal feed for meat production, particularly in cattle, is limited. To the best of our knowledge, only one study (Hill, Utley & Newton, 1986) evaluated the effect of PS on nutrient digestibility and performance of beef cattle. Authors did not observe improvements in digestibility and nitrogen retention in animals fed either with urea-supplemented PS or ammoniated PS (15%). In addition, other important indicators for meat

production such as average daily gains, carcass weights and quality grades were not influenced by both PS enriched diets.

Although the use of PS in animal feed is limited and not well known, the inclusion of PSE in meat products is an interesting alternative to synthetic compounds, particularly as a source of antioxidant compounds to prevent oxidative reactions (**Fig. 3**).

In ground beef, a methanolic PSE (200 ppm) prevented lipid oxidation and did not affect the instrumental color, sensory aroma, cooking loss and microbial growth in cooked ground beef during 14 of refrigerated storage. However, the authors observed that PS levels higher than 400 ppm (600 and 800 ppm) reduced the luminosity, redness and yellowness of cooked ground beef. In addition, salt, phosphate and nitrite with erythorbate (widely used in meat industries) did not affect the antioxidant activity of PS (O'Keefe & Wang, 2006). Likewise, Munekata et al. (2016) observed that 200 ppm of PSE in raw sheep patties packaged in modified atmosphere (80% O₂ – 20% CO₂) reduced the loss of redness, prevented both lipid and protein oxidation and decreased changes in sensory attributes (red color intensity, superficial discoloration and off-odor) during refrigerated storage. However, PSE did not affect the free fatty acid content, microbial growth and volatile compounds derived from lipid oxidation.

In the study performed by Yu, Ahmedna and Goktepe (2010), the raw and cooked ground beef with 0.6% PSE and the mixture of BHA/BHT at 0.02% displayed a similar effect on the inhibition of hydroperoxides and thiobarbituric acid reactive substances (TBARS) accumulation during 12 days of refrigerated storage. Protein oxidation was reduced in 0.02–0.10% PSE treatments. The

loss of redness was partially inhibited by 0.4% or higher levels of PSE. The authors also evaluate the PS antimicrobial potential in microplates against pathogenic bacteria (*Bacillus subtilis*, *Salmonella typhimurium*, *Staphylococcus aureus*, *Streptococcus faecalis* and *Escherichia coli*) and reported the complete inhibition of these microorganisms by PSE (at least 0.4%). However, authors observed that PS antimicrobial effect was reduced in raw ground beef and stated that dilution of extract and interaction with matrix could explain such results.

In another study with cooked chicken patties, an aqueous extract obtained from PS (3%) inhibited the lipid oxidation and prevented the loss of redness during 15 days of refrigerated storage. Similarly to previous studies with PS in meat products, a significant reduction in lightness was observed in PS treatments (Munekata et al., 2015).

The effect of PSE in the chemical stability and sensory properties during storage of salami were evaluated by Larrauri et al. (2013). The authors observed that salami elaborated with PSE (0.1 g/100 g) and BHT reduced both peroxide value and conjugated dienes generation compared to control and PS extract (0.02 g/100 g) treatments after 14 days of storage. No significant impact in sensory attributes due to PSE addition was indicated by authors in a sensory evaluation of salami regarding its appearance, aroma/flavor, basic tastes, mouthfeel and texture. Principal Component Analysis revealed that control, PSE (0.02 g/100 g) peroxide value, conjugated dienes, oxidized flavor and rancid odor were located in the same side of the plot while PSE (0.1 g/100 g) and BHT treatments were located in the opposite side of the plot along with salami flavor, salami odor and beef color. However, authors did not observe any

protective effect against free fatty acid (FFA) release during storage of PS treatments but showed an increase in the FFA content due to the addition of PSE in salami.

Munekata et al. (2017) observed that PSE (2000 mg/kg) had no effect on pH, chemical composition and color (a^* and b^* value) of Spanish *salchichón* elaborated with long chain n-3 polyunsaturated fatty acids (PUFA) in konjac glucomannan matrix. Protein oxidation and the content of aldehydes derived from lipid oxidation were both reduced in PS treatment in comparison to control while lipid oxidation, evaluated by TBARS assay, and FFA content were not affected. Although different results were reported by authors regarding oxidative indexes, these results were attributed to *salchichón* structure which influenced the interaction between the long chain n-3 PUFA and phenolic compounds from PSE (mainly composed by catechin and protocatechuic acid).

7. Concluding remarks

The large body of evidence indicates that PS is an interesting source of natural antioxidants, mainly due to of its high content in proanthocyanidin compounds. Although the information about PS use as animal feed for meat products is limited and indicate no substantial contribution in meat productive system, the use of PS in meat products strengthen the hypothesis that PS can be applied as natural antioxidant since minor changes in sensory properties and physico-chemical characteristics were reported. The antimicrobial potential of PSE requires further research since insufficient and controversial information is reported in the literature between the *in vitro* results and those with application in meat products.

References

- Alam, M. N., Bristi, N. J., & Rafiquzzaman, M. (2013). Review on in vivo and in vitro methods evaluation of antioxidant activity. *Saudi Pharmaceutical Journal*, 21(2), 143-152.
- Alves, M. J., Ferreira, I. C. F. R., Froufe, H. J. C., Abreu, R. M. V, Martins, A., & Pintado, M. (2013). Antimicrobial activity of phenolic compounds identified in wild mushrooms, SAR analysis and docking studies. *Journal of Applied Microbiology*, 115(2), 346–357.
- Appeldoorn, M. M., Vincken, J. P., Sanders, M., Hollman, P. C., & Gruppen, H. (2009). Combined normal-phase and reversed-phase liquid chromatography/ESI-MS as a tool to determine the molecular diversity of A-type procyanidins in peanut skins. *Journal of Agricultural and Food Chemistry*, 57(14), 6007-6013.
- Aziz, M., & Karboune, S. (2017). Natural antimicrobial/antioxidant agents in meat and poultry products as well as fruits and vegetables: A review. *Critical Reviews in Food Science and Nutrition*, 1–26.
- Badarinath, A. V., Rao, K. M., Chetty, C. M. S., Ramkanth, S., Rajan, T. V. S., & Gnanaprakash, K. (2010). A review on in-vitro antioxidant methods: comparisons, correlations and considerations. *International Journal of PharmTech Research*, 2(2), 1276-1285.
- Ballard, T. S., Mallikarjunan, P., Zhou, K., & O'Keefe, S. (2010). Microwave-assisted extraction of phenolic antioxidant compounds from peanut skins. *Food Chemistry*, 120(4), 1185-1192.
- Barba, F. J., Parniakov, O., Pereira, S. A., Wiktor, A., Grimi, N., Boussetta, N., ... Vorobiev, E. (2015). Current applications and new opportunities for the

489 use of pulsed electric fields in food science and industry. *Food Research*
 490 *International*, 77, Part 4, 773–798.

491 Barba, F. J., Terefe, N. S., Buckow, R., Knorr, D., & Orlie, V. (2015). New
 492 opportunities and perspectives of high pressure treatment to improve
 493 health and safety attributes of foods. A review. *Food Research*
 494 *International*, 77, Part 4, 725–742.

495 Barba, F. J., Zhu, Z., Koubaa, M., Sant'Ana, A. S., & Orlie, V. (2016). Green
 496 alternative methods for the extraction of antioxidant bioactive compounds
 497 from winery wastes and by-products: A review. *Trends in Food Science*
 498 *and Technology*, 49, 96–109.

499 Berton-Carabin, C. C., Ropers, M. H., & Genot, C. (2014). Lipid oxidation in
 500 oil-in-water emulsions: involvement of the interfacial layer. *Comprehensive*
 501 *Reviews in Food Science and Food Safety*, 13(5), 945-977.

502 Bodoira, R., Rossi, Y., Montenegro, M., Maestri, D., & Velez, A. (2017).
 503 Extraction of antioxidant polyphenolic compounds from peanut skin using
 504 water-ethanol at high pressure and temperature conditions. *The Journal of*
 505 *Supercritical Fluids*, 128, 57-65.

506 Borch, E., Kant-Muermans, M. L., & Blixt, Y. (1996). Bacterial spoilage of meat
 507 and cured meat products. *International Journal of Food Microbiology*,
 508 33(1), 103-120.

509 Braga, G. C., Melo, P. S., Bergamaschi, K. B., Tiveron, A. P., Massarioli, A. P.,
 510 & Alencar, S. M. D. (2016). Extraction yield, antioxidant activity and
 511 phenolics from grape, mango and peanut agro-industrial by-products.
 512 *Ciência Rural*, 46(8), 1498-1504.

513 Caroch, M., & Ferreira, I. C. (2013). A review on antioxidants, prooxidants and
 514 related controversy: natural and synthetic compounds, screening and
 515 analysis methodologies and future perspectives. *Food and Chemical*
 516 *Toxicology*, 51, 15-25.

517 Chemat, F., Vian, M. A., & Cravotto, G. (2012). Green extraction of natural
 518 products: concept and principles. *International Journal of Molecular*
 519 *Sciences*, 13(7), 8615–8627.

520 Chukwumah, Y., Walker, L. T., & Verghese, M. (2009). Peanut skin color: a
 521 biomarker for total polyphenolic content and antioxidative capacities of
 522 peanut cultivars. *International Journal of Molecular Sciences*, 10(11),
 523 4941-4952.

524 Daglia, M. (2012). Polyphenols as antimicrobial agents. *Current Opinion in*
 525 *Biotechnology*, 23(2), 174-181.

526 Davis, J. P., Dean, L. L., Price, K. M., & Sanders, T. H. (2010). Roast effects on
 527 the hydrophilic and lipophilic antioxidant capacities of peanut flours,
 528 blanched peanut seed and peanut skins. *Food Chemistry*, 119(2), 539-
 529 547.

530 De Camargo, A. C., Regitano-d'Arce, M. A. B., Gallo, C. R., & Shahidi, F.
 531 (2015). Gamma-irradiation induced changes in microbiological status,
 532 phenolic profile and antioxidant activity of peanut skin. *Journal of*
 533 *Functional Foods*, 12, 129-143.

534 De Camargo, A. C., Vieira, T. M. F. D. S., Regitano-D'Arce, M. A. B., Calori-
 535 Domingues, M. A., & Canniatti-Brazaca, S. G. (2012). Gamma radiation
 536 effects on peanut skin antioxidants. *International Journal of Molecular*
 537 *Sciences*, 13(3), 3073-3084.

538 De Camargo, A. C., Regitano-d'Arce, M. A. B., Rasera, G. B., Canniatti-
 539 Brazaca, S. G., do Prado Silva, L., Alvarenga, V. O., Sant'Ana, A. S., &
 540 Shahidi, F. (2017). Phenolic acids and flavonoids of peanut by-products:
 541 Antioxidant capacity and antimicrobial effects. *Food Chemistry*, 237, 538-
 542 544.

543 Cueva, C., Moreno-Arribas, M. V, Martín-Álvarez, P. J., Bills, G., Vicente, M. F.,
 544 Basilio, A., ... Bartolomé, B. (2010). Antimicrobial activity of phenolic acids
 545 against commensal, probiotic and pathogenic bacteria. *Research in*
 546 *Microbiology*, 161(5), 372–382.

547 EFSA (European Food Safety Authority) (2011). Scientific opinion on the
 548 reevaluation of butylated hydroxyanisol – BHA (E 320) as a food additive.
 549 *EFSA Journal*, 9(10), 2392, <http://dx.doi.org/10.2903/j.efsa.2011.2392>.

550 EFSA (European Food Safety Authority) (2012). Scientific Opinion on the re-
 551 evaluation of butylated hydroxytoluene BHT (E 321) as a food additive.
 552 *EFSA Journal*, 10(3), 2588, <http://dx.doi.org/10.2903/j.efsa.2012.2588>.

553 Falowo, A. B., Fayemi, P. O., & Muchenje, V. (2014). Natural antioxidants
 554 against lipid–protein oxidative deterioration in meat and meat products: A
 555 review. *Food Research International*, 64, 171-181.

556 Faustman, C., & Cassens, R. G. (1990). The biochemical basis for discoloration
 557 in fresh meat: a review. *Journal of Muscle Foods*, 1(3), 217-243.

558 Faustman, C., Sun, Q., Mancini, R., & Suman, S. P. (2010). Myoglobin and lipid
 559 oxidation interactions: Mechanistic bases and control. *Meat Science*,
 560 86(1), 86-94.

561 Francisco, M. L., & Resurreccion, A. V. A. (2009). Development of a reversed-
 562 phase high performance liquid chromatography (RP-HPLC) procedure for

563 the simultaneous determination of phenolic compounds in peanut skin
 564 extracts. *Food Chemistry*, 117(2), 356-363.

565 Frankel, E. N. (1991). Review. Recent advances in lipid oxidation. *Journal of the*
 566 *Science of Food and Agriculture*, 54(4), 495-511.

567 Galanakis, C. M. (2012). Recovery of high added-value components from food
 568 wastes: Conventional, emerging technologies and commercialized
 569 applications. *Trends in Food Science & Technology*, 26(2), 68–87.

570 Galanakis, C. M. (2013). Emerging technologies for the production of
 571 nutraceuticals from agricultural by-products: A viewpoint of opportunities
 572 and challenges. *Food and Bioproducts Processing*, 91(4), 575–579.

573 Gram, L., Ravn, L., Rasch, M., Bruhn, J. B., Christensen, A. B., & Givskov, M.
 574 (2002). Food spoilage—interactions between food spoilage bacteria.
 575 *International Journal of Food Microbiology*, 78(1), 79-97.

576 Hill, G. M., Utley, P. R., & Newton, G. L. (1986). Digestibility and utilization of
 577 ammonia-treated and urea-supplemented peanut skin diets fed to cattle.
 578 *Journal of Animal Science*, 63(3), 705-714.

579 Hoang, V. H., Apoštolová, P., Dostálová, J., Pudil, F., Pokorný, J. (2008).
 580 Antioxidant activity of peanut skin extracts from conventional and high-
 581 oleic peanuts. *Czech Journal of Food Science*, 26(6), 447-457.

582 Hung, Y., de Kok, T. M., & Verbeke, W. (2016). Consumer attitude and
 583 purchase intention towards processed meat products with natural
 584 compounds and a reduced level of nitrite. *Meat Science*, 121, 119-126.

585 Jayasena, D. D., & Jo, C. (2013). Essential oils as potential antimicrobial agents
 586 in meat and meat products: A review. *Trends in Food Science &*
 587 *Technology*, 34(2), 96-108.

588 Jayasena, D. D., & Jo, C. (2014). Potential application of essential oils as
 589 natural antioxidants in meat and meat products: a review. *Food Reviews*
 590 *International*, 30(1), 71-90.

591 Koubaa, M., Mhemdi, H., Barba, F. J., Roohinejad, S., Greiner, R., & Vorobiev,
 592 E. (2016). Oilseed treatment by ultrasounds and microwaves to improve oil
 593 yield and quality: An overview. *Food Research International*, 85, 59–66.

594 Larrauri, M., Barrionuevo, M. G., Riveros, C., Mestrallet, M. G., Zunino, M. P.,
 595 Zygodlo, J. A., Grosso, N. R., & Nepote, V. (2013). Effect of peanut skin
 596 extract on chemical stability and sensory properties of salami during
 597 storage. *Journal of the Science of Food and Agriculture*, 93(7), 1751-1757.

598 Larrauri, M., Zunino, M. P., Zygodlo, J. A., Grosso, N. R., & Nepote, V. (2016).
 599 Chemical characterization and antioxidant properties of fractions
 600 separated from extract of peanut skin derived from different industrial
 601 processes. *Industrial Crops and Products*, 94, 964-971.

602 Liu, Z. Q., Yang, Q. L., Zhang, C. S., Sun, J., Zhang, Y., & Wang, S. Q. (2011).
 603 Optimization of ultrasonic extraction technique of proanthocyanidin from
 604 peanut skin. *Advanced Materials Research*, 156-157, 778-784.

605 Lou, H., Yamazaki, Y., Sasaki, T., Uchida, M., Tanaka, H., & Oka, S. (1999). A-
 606 type proanthocyanidins from peanut skins. *Phytochemistry*, 51(2), 297-
 607 308.

608 Lou, H., Yuan, H., Ma, B., Ren, D., Ji, M., & Oka, S. (2004). Polyphenols from
 609 peanut skins and their free radical-scavenging effects. *Phytochemistry*,
 610 65(16), 2391-2399.

611 Lou, H., Yuan, H., Yamazaki, Y., Sasaki, T., & Oka, S. (2001). Alkaloids and
 612 flavonoids from peanut skins. *Planta Medica*, 67(04), 345-349.

613 Lucchini, J. J., Corre, J., & Cremieux, A. (1990). Antibacterial activity of phenolic
 614 compounds and aromatic alcohols. *Research in Microbiology*, 141(4),
 615 499–510.

616 Lucera, A., Costa, C., Conte, A., & Del Nobile, M. A. (2012). Food applications
 617 of natural antimicrobial compounds. *Frontiers in Microbiology*, 3.
 618 doi:10.3389/fmicb.2012.00287

619 Lund, M. N., Heinonen, M., Baron, C. P. & Estévez, M. (2011). Protein oxidation
 620 in muscle foods: A review. *Molecular Nutrition & Food Research*, 55, 83-
 621 95

622 Ma, Y., Kosińska-Cagnazzo, A., Kerr, W. L., Amarowicz, R., Swanson, R. B., &
 623 Pegg, R. B. (2014). Separation and characterization of phenolic
 624 compounds from dry-blanching peanut skins by liquid chromatography–
 625 electrospray ionization mass spectrometry. *Journal of Chromatography A*,
 626 1356, 64-81.

627 Maddox, C. E., Laur, L. M., & Tian, L. (2010). Antibacterial activity of phenolic
 628 compounds against the phytopathogen *Xylella fastidiosa*. *Current*
 629 *Microbiology*, 60(1), 53–58.

630 Min, B., & Ahn, D. U. (2005). Mechanism of lipid peroxidation in meat and meat
 631 products-A review. *Food Science and Biotechnology*, 14(1), 152-163.

632 Moure, A., Cruz, J. M., Franco, D., Domínguez, J. M., Sineiro, J., Domínguez,
 633 H., Núñez, M. J., & Parajó, J. C. (2001). Natural antioxidants from residual
 634 sources. *Food Chemistry*, 72(2), 145-171.

635 Munekata, P. E. S., Calomeni, A. V., Rodrigues, C. E. C., Fávaro-Trindade, C.
 636 S., Alencar, S. M., & Trindade, M. A. (2015). Peanut skin extract reduces
 637 lipid oxidation in cooked chicken patties. *Poultry Science*, 94(3), 442-446.

638 Munekata, P. E. S., Domínguez, R., Franco, D., Bermúdez, R., Trindade, M. A.,
639 & Lorenzo, J. M. (2017). Effect of natural antioxidants in Spanish
640 salchichón elaborated with encapsulated n-3 long chain fatty acids in
641 konjac glucomannan matrix. *Meat Science*, 124, 54-60.

642 Munekata, P. E. S., Fernandes, R. D. P. P., de Melo, M. P., Trindade, M. A., &
643 Lorenzo, J. M. (2016). Influence of peanut skin extract on shelf-life of
644 sheep patties. *Asian Pacific Journal of Tropical Biomedicine*, 6(7), 586-
645 596.

646 Nepote, V., Grosso, N. R., & Guzmán, C. A. (2002). Extraction of antioxidant
647 components from peanut skins. *Grasas y Aceites*, 53(4), 391-395.

648 Nepote, V., Grosso, N. R., & Guzmán, C. A. (2005). Optimization of extraction
649 of phenolic antioxidants from peanut skins. *Journal of the Science of Food
650 and Agriculture*, 85(1), 33-38.

651 O'Keefe, S. F., & Wang, H. (2006). Effects of peanut skin extract on quality and
652 storage stability of beef products. *Meat Science*, 73(2), 278-286.

653 Oldoni, T. L., Melo, P. S., Massarioli, A. P., Moreno, I. A., Bezerra, R. M.,
654 Rosalen, P. L., Silva, G. V. J., Nascimento, A. M., & Alencar, S. M. (2016).
655 Bioassay-guided isolation of proanthocyanidins with antioxidant activity
656 from peanut (*Arachis hypogaea*) skin by combination of chromatography
657 techniques. *Food Chemistry*, 192, 306-312.

658 Pizzolitto, R. P., Dambolena, J. S., Zunino, M. P., Larrauri, M., Grosso, N. R.,
659 Nepote, V., Dalcero, A. M., & Zygodlo, J. A. (2013). Activity of natural
660 compounds from peanut skins on *Fusarium verticillioides* growth and
661 fumonisin B 1 production. *Industrial Crops and Products*, 47, 286-290.

662 Proestos, C., Boziaris, I. S., Nychas, G.-J. E., & Komaitis, M. (2006). Analysis of
 663 flavonoids and phenolic acids in Greek aromatic plants: Investigation of
 664 their antioxidant capacity and antimicrobial activity. *Food Chemistry*, 95(4),
 665 664–671.

666 Puértolas, E., & Barba, F. J. (2016). Electrotechnologies applied to valorization
 667 of by-products from food industry: Main findings, energy and economic
 668 cost of their industrialization. *Food and Bioproducts Processing*, 100, Part
 669 A, 172–184.

670 Rodríguez Vaquero, M. J., Alberto, M. R., & de Nadra, M. C. (2007).
 671 Antibacterial effect of phenolic compounds from different wines. *Food*
 672 *Control*, 18(2), 93–101.

673 Rombaut, N., Tixier, A.-S., Bily, A., & Chemat, F. (2014). Green extraction
 674 processes of natural products as tools for biorefinery. *Biofuels*,
 675 *Bioproducts and Biorefining*, 8(4), 530–544.

676 Roohinejad, S., Koubaa, M., Barba, F. J., Greiner, R., Orlie, V., & Lebovka, N.
 677 I. (2016). Negative pressure cavitation extraction: A novel method for
 678 extraction of food bioactive compounds from plant materials. *Trends in*
 679 *Food Science & Technology*, 52, 98–108.

680 Ross, C. F., & Smith, D. M. (2006). Use of volatiles as indicators of lipid
 681 oxidation in muscle foods. *Comprehensive Reviews in Food Science and*
 682 *Food Safety*, 5(1), 18-25.

683 Sarnoski, P. J., Boyer, R. R., & O’Keefe, S. F. (2012). Application of
 684 proanthocyanidins from peanut skins as a natural yeast inhibitory agent.
 685 *Journal of Food Science*, 77(4), M242-M249.

686 Sarnoski, P. J., Johnson, J. V., Reed, K. A., Tanko, J. M., & O'Keefe, S. F.
687 (2012). Separation and characterisation of proanthocyanidins in Virginia
688 type peanut skins by LC–MSn. *Food Chemistry*, 131(3), 927-939.

689 Shahidi, F., & Ambigaipalan, P. (2015). Phenolics and polyphenolics in foods,
690 beverages and spices: Antioxidant activity and health effects – A review.
691 *Journal of Functional Foods*, 18, 820-897.

692 Shahidi, F., & Pegg, R. B. (1994). Hexanal as an indicator of meat flavor
693 deterioration. *Journal of Food Lipids*, 1(3), 177-186.

694 Shem-Tov, Y. O. A. V., Badani, H., Segev, A., Hedvat, I., Galili, S., & Hovav, R.
695 A. N. (2012). Determination of total polyphenol, flavonoid and anthocyanin
696 contents and antioxidant capacities of skins from peanut (*Arachis*
697 *hypogaea*) lines with different skin colors. *Journal of Food Biochemistry*,
698 36(3), 301-308.

699 Sobolev, V. S., & Cole, R. J. (2004). Note on utilisation of peanut seed testa.
700 *Journal of the Science of Food and Agriculture*, 84(1), 105-111.

701 Soladoye, O. P., Juárez, M. L., Aalhus, J. L., Shand, P., & Estévez, M. (2015).
702 Protein oxidation in processed meat: Mechanisms and potential
703 implications on human health. *Comprehensive Reviews in Food Science*
704 *and Food Safety*, 14(2), 106-122.

705 Tamura, T., Ozawa, M., Tanaka, N., Arai, S., & Mura, K. (2016). *Bacillus cereus*
706 response to a proanthocyanidin trimer, a transcriptional and functional
707 analysis. *Current Microbiology*, 73(1), 115-123.

708 Van Ha, H., Pokorný, J., & Sakurai, H. (2007). Peanut skin antioxidants. *Journal*
709 *of Food Lipids*, 14(3), 298-314.

710 Wang, J., Yuan, X., Jin, Z., Tian, Y., & Song, H. (2007). Free radical and
 711 reactive oxygen species scavenging activities of peanut skins extract.
 712 *Food Chemistry*, 104(1), 242-250.

713 Wen, A., Delaquis, P., Stanich, K., & Toivonen, P. (2003). Antilisterial activity of
 714 selected phenolic acids. *Food Microbiology*, 20(3), 305–311.

715 Win, M. M., Abdul-Hamid, A., Baharin, B. S., Anwar, F., Sabu, M. C., Pak-Dek,
 716 M. S. (2011). Phenolic compounds and antioxidant activity of peanuts skin,
 717 hull, raw kernel and roasted kernel flour. *Pakistan Journal of Botany*,
 718 43(3), 1635-1642.

719 Yu, J., Ahmedna, M., & Goktepe, I. (2005). Effects of processing methods and
 720 extraction solvents on concentration and antioxidant activity of peanut skin
 721 phenolics. *Food Chemistry*, 90, 199-206.

722 Yu, J., Ahmedna, M., & Goktepe, I. (2010). Potential of peanut skin phenolic
 723 extract as antioxidative and antibacterial agent in cooked and raw ground
 724 beef. *International Journal of Food Science & Technology*, 45(7), 1337-
 725 1344.

726 Yu, J., Ahmedna, M., Goktepe, I., & Dai, J. (2006). Peanut skin procyanidins:
 727 Composition and antioxidant activities as affected by processing. *Journal*
 728 *of Food Composition and Analysis*, 19(4), 364-371.

729

FIGURE CAPTION

Figure 1. Peanut skin (PS) predominant phenolic compounds

Figure 2. Steps in the extraction of high-added value compounds from
peanut skin to be used in meat formulation

Figure 3. Beneficial effects of peanut skin phenolic compounds in meat
products

Figure 1

Figure 2

Figure 3

Table 1. Effect of extraction conditions and peanut variety in the phenolic and flavonoid content of peanut skin extracts

Variety	Solvent, (ratio sample/solvent), time of extraction, <i>n</i> ^a	Phenolic content	Flavonoid content	Reference
n.i. ^b	80% ethanol, (1:10), 15 min, 3	404.40±13.22 mg GAE/g	16.14 mg quercetin equivalent/g	Braga et al. (2016)
Runner, Valencia, Virginia and Spanish	80% metanol, (2:3), 20 min, 1	94.4 - 228.4 mg GAE/100 g	27.6 - 139.9 mg catechin equivalent/100 g	Chukwumah et al. (2009)
Runner	methanol; (1:2500), 20 min 1	79.36±1.94mg GAE/g ^c	n.d.	de Camargo et al. (2012)
Virginia, Valencia, Runner and mix of varieties	50% acetone, (1:10), 15-19 h, 1	5 - 156 mg catechin/g	5 - 140 mg catechin equivalent/g	Shem-Tov et al. (2012)
Virginia	hexane, (1:10), overnight, 3	0.69 ± 0.12 % GAE of skin	n.d.	Van Ha, Pokorný and Sakuri (2007)
	ethyl acetate, (1:10), overnight, 3	47.19 ± 1.21 % GAE of skin	1.22 ± 0.06 % of rutin equivalent	
	methanol, (1:10), overnight, 3	65.31 ± 0.73 % GAE of skin	0.62 ± 0.10 % of rutin equivalent	
n.i.	50% ethanol, (1:75), overnight, 2	0.097 g GAE/g	0.065 g catechin equivalent/g	Wang et al. (2007)
Virginia	methanol, (1:10), 2 h, 3	91.74 ± 5.08 mg GAE/g	n.d. ^d	Win et al. (2011)

^a number of sequential extractions; ^b n.i. – not informed; ^c GAE – gallic acid equivalent; ^d n.d. – not determined