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A Review on Onion Skin, a Natural Dye Source

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Abstract

The skin of the onion plant is a natural waste product. In this context, it is possible to evaluate their use in natural dyeing (cotton, wool, silk, etc.) and in lake pigment production by extracting the dyestuffs in these wastes. The skin that forms this outermost part contains some flavonoid (quercetin, etc.) and anthocyanidin (pelargonidin, etc.) natural dyestuffs. Quercetin glycosides are flavonoids liable for the majority of the flavonols in the plant. The amount of quercetin may increase from the inner part of the onion plant to the outer part. It is known that onion skin has been used in wool dyeing from past to present. It has traditionally been used in carpets and rugs. Onion skin was used in Anatolia, Turkey, where carpets and rugs were produced.

Keywords: Onion skin, dye, quercetin, natural dyeing, textile.

Introduction

The dry onion production area in the world has a remarkable situation. Turkey is 3rd in the global in the way of dry onion production after India and the USA. In Turkey, the outer skins of the plant have been used for natural coloring in the textile industry for a long time. As a result of this, economic gain and employment area can be obtained as to natural dyes from these vegetable wastes [1,2].

Onion is a food product that is generally available on the table in Turkey. It can be said that this product maintains its presence in both meals and salads besides it has rich ingredients. After their use, the onion skins go to waste. Thence, these wastes may be useful in the dyeing of hand-woven carpets and rugs [3].

Plant-based dyes giving a color were valuable because of the dyeing of fibers in antiquity. For these plants, the dyes in obtaining the colors are important information. It can be said that this situation depends on present-day dyeing recipes or the dyeing recipes in historical documents [4].

These dyes are still in use today for example, in floor coverings, rugs, fabric dyeing and leather production, etc. It is also used in industry and various fields such as art studies [5].

It can be said that natural dyeing can be provided from approximately seven hundred plant-based dye sources in the world [6].

Literature Review

Onion Skin Dye – Quercetin

In particular, onion skin, which is a waste from agricultural products can be recycled in terms of obtaining natural dyes [7].

The Turkish name of Allium cepa (onion) is “soğan”. Yellow, beige, and reddish-brown colors can be provided from the skins of this dye source. This dye source is widely used in Anatolia [8].

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Onion skin is a natural source of brown dye and includes mainly quercetin (3,3′,4′,5,7-pentahydroxy flavone) dyestuff. This dyestuff exists as yellow crystals. Its melting point is 316-317°C and its chemical formula is $C_{15}H_{10}O_7$. This dye source concerns the Liliaceae family and arises from the Middle East [9].

In Figure 1, the structure of quercetin is given.

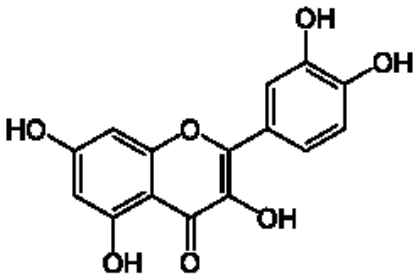

Fig. 1. Structure of quercetin [10].

Quercetin, as of today, is a flavonoid compound that has been extensively studied by researchers around the World [11].

It can be utilized to dye textile fibers, especially, cotton [12].

This flavonol compound is most particularly a dye used in central Anatolian carpets [13].

In Figure 2, the backbone of flavonol is given.

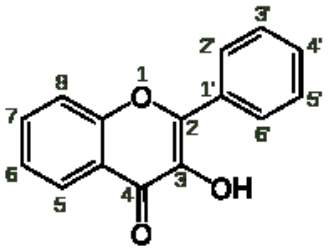

Fig. 2. The backbone of a flavonol [14].

Quercetin is one of the most studied flavonols. Onion is fairly rich in flavonols [15].

The last twenty-five flavonols present in the onion were determined [16].

It can be said that quercetin dyestuff was initially extracted from the oak tree (Quercus rubra). For quercetin, the characterized 135 apart glycosides are presented [17].

It has an aglycone structure. This structure does not contain a sugar bound to the molecule. It is substantially soluble in alcohol. But it is exactly insoluble in cold water. Apart from these, it is slightly soluble in hot water [18].

This dyestuff can be also used as an extract that gives a yellow color in dyeing. It is a durable compound against washing and abrasion in terms of lightfastness [19].

It is a flavonol compound relating to the class of flavonoids one of two important groups of natural dyes. Flavonols have higher colorfastness than flavones [20].

Alum substance is a mordant which is commonly used in natural dyeing. This mordant can provide shiny colors and wash fastness with natural dyes such as flavonoids in the coloring of keratin fibers [21].

Flavonoids are related to most yellow dye compounds. The skins of onion (Allium cepa) generate a natural dye that is very poor in terms of lightfastness [22].

A flavonoid compound can be used as a dyestuff present in the dye and the lake pigments. This compound is among powerful chelators. It can be said that lake pigments are obtained in the form of an indissoluble stable complex [23].

Onion can act as a flavonoid dye source. In onion, approximately 93 % of totally flavonol components are related to the quercetin diglycoside and monoglycoside. If quercetin flavonol ingredients in onion are wanted to double, a lamp that emitted UV light can be used after harvesting. Compared to the edible parts of onion, the dry outer skins have remarkably higher quercetin ingredients. From the onion's outer skin up to the inner parts of the onion, its quercetin content is decreased. This situation is acceptable for both fresh and dry onion weight [24].

The name quercetin is derived from quercetum. Quercetum is based on the Latin Word. This name means Oak Forest [25,26].

The flavonol of quercetin cannot be synthesized by the human body [25].

Onion contains flavonoids with quercetin arranging traces in white to 2.5-3 mmol/kg in red varieties. It was reported that yellow onions include approximately 0.7-1 mmol/kg quercetin derivatives. Quercetin is tufted in the skin of most onions. This dye discloses a tawny color [27].

Onion skin was used especially for the manufacture of dyed material on a small scale in northern Europe. It was also utilized for the coloring of the cotton floor covering to a yellow color in Persia long ago. Khaki-colored costumes became a trend in Japan instantly after the Second World War. The material here was cotton textiles treated with an iron mordant called "welfare dyeing" and dyed with onion skin extract [28].

It is known that there was a shortage of dye in Turkey during the First World War, and therefore tents and clothes were dyed with walnut leaves and onion skins. In the weaving of Uşak carpets and kilims, natural dyestuffs were used in dyeing wool yarns. In addition to the use of madder, it has been determined that one of the sources of dyestuffs is also onion skin [29].

Allium cepa L. (Liliaceae) is generally called an onion. Its earliest use appeared in ancient Egypt [30].

As a mean, onion skins are responsible for 10-25 % (% w/w basis) in terms of all weight of the onion [31].

Onion skin is a valuable dye source of quercetin. This dye source contains mainly two flavonoid molecules, quercetin aglycone, and quercetin-4′-glycoside. Quercetin compound is a powerful antioxidant [32].

Quercetin is accumulated in the skin of a large part of onions. Onion skin gives a yellowish-brown color. The flavonoids in the skin are generally found as aglycones. They are quercetin aglycone and quercetin-4′-glycoside. Besides, it can be said that the anthocyanins in the onion skin are also responsible for 2 % of the total mass [33].

Onion skins include the historically important dyestuffs giving a yellow color. They mainly contain flavonoids named quercetin, quercetin-3-O-glycoside, and kaempferol [34].

These skins have historically been used in coloring textiles to produce dark yellow and orange tones in Europe and Arab countries [35].

Quercetin dyestuff work as a ligand in the removal of copper and other metals from aqueous salt solutions [36].

In terms of its physical properties, quercetin is related to a lipophilic character. Its derivatives can exhibit both lipo- and hydrophilic properties. This is related to the type of substituents present in the molecule [37].

This dyestuff is a phenolic compound. The existence of - OH or - C=O groups in the structure is necessary to obtain the metal-flavonoid complex. In this sense, the flavonoid can generate the complex with positively charged metals [38].

One of the main dye compounds present in onion skins (Allium cepa) is also quercetin. Quercetin dyestuff co-exists with various related flavonols. The "Navajo Dye Chart" art poster lists some types of onions used as dyes by the Navajo. These types of onions include wild onions and red and brown onion skins [39].

Navajo dyers used red onion skins to get a green color [40].

Onion skins have been used to dye fabrics for ages. Yellow globular bulbs on wool give a dark shade of orange and brass color [41].

These skins are used to dye wool in Anatolia from past to present [17,42].

In the production of the dyes used in the carpet cushions of the Konya Karapınar region, red tile color is obtained by boiling the wool fiber dyed with dry onion skin with the peeled-madder root for 1-2 hours [43].

Spurge, mullein, walnut shell, pomegranate peel, onion skin plants, etc. are rarely used today for dyeing Goşken rugs in Şenkaya region, one of the northeastern districts of Erzurum [44].

Onion is scientifically called Allium cepa [45].

Its dry skin was used to dye in classical Greece, Persia, and the Middle East, and by primitive tribes of Africa. Besides, in central Europe, it was also utilized as a dye for Easter eggs, linen, wool, and particularly cotton. At the same time, it is known that the onion skins can be used in textile production places and dyeing eggs as a vegetable dye. It may be possible to use vegetable-made dyes from these onion skins for staining eggs or items of clothing [46].

TABLE 1. The physical properties of the quercetin compound

Formula	$C_{15}H_{10}O_7$
Molecular Weight	302,24 g/mol
Composition	65,19 % C, 3,34 % H and 37,06 % O
Purity	≥ 95 %
Melting Point	314 °C
UV Maxima	258, 375 nm (ethanol)
Appearance	A solid powder that has a mustard yellow color
Solubility	It is solved in alcohol and it is not solved hardly ever in the water. Besides, it is solved by giving an intense yellow color to acetic acid.
Storage conditions	It should be stored at +4 °C, protected from sunlight

In Table 1, the physical properties of the quercetin compound were given.

Quercetin is used in the fields of biochemistry, food chemistry, and dye chemistry. It is also used as a yellow dye extract. Its fastness of (light, washing, perspiration, rubbing, and abrasion) extract is high [47].

The principal dyestuff compounds in the onion skin are flavonols like isorhamnetin-3-O-glycoside, kaempferol, glycoside rutin, quercetin, quercetin-4′,7-O-diglycoside, quercetin-3,7-O-diglycoside, quercetin-4′-O-glycoside, and isoquercetin. It has been reported that quercetin is above 53 % in onion skin extracts [48].

Onion (Allium cepa) skin can contain also a protocatechuic acid. This compound is chemically called 3,4-dihyroxybenzoic acid. It is naturally formed in terms of some plants [49].

Pelargonidin Dye

Generally, onion plants contain compounds such as phenolics and flavonoids. The peel includes a dyestuff compound named pelargonidin (Figure 3) [50]. This compound is an anthocyanidin. Its IUPAC name is 3,4′,5,7-tetrahydroxyflavylium[51]. The outermost skin of the onion also contains some tannin compounds [52].

In Figure 4, structure of flavylium cation was given. The physical properties of pelargonidin compound were also shown in Table 2.

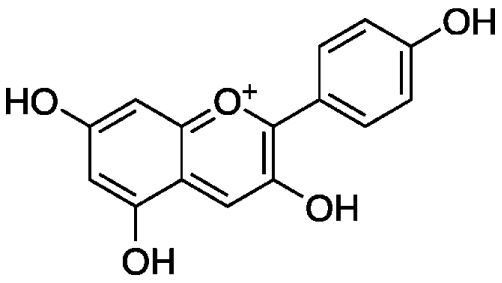

Fig. 3. Structure of pelargonidin compound [53].

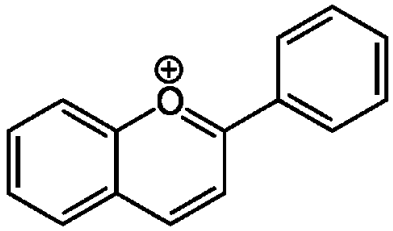

Fig. 4. Structure of flavylium cation [54].

TABLE 2. The physical properties of the pelargonidin compound

Molecular formula	$C_{15}H_{11}O_5^+$
Molecular weight	271.24 g/mol
Physical description	Solid
Melting point	>350ºC
	[55].
IUPAC name	3,4',5,7-Tetrahydroxyflavylium
	[53].

This waste includes a pelargonidin dyestuff compound. This compound can be used in the coloring of some materials (leather, textile, and paper), and the food industry as a coloring. At the same time, it can be used as a natural dye that gives a deep red color in an aqueous medium and a dark pink color in acetic acid [56]. The amount of pelargonidin, a coloring pigment present in onion (Allium cepa) skin, ranges from 2.0 % to 2.25 % [57]. The pelargonidin compounds act as acid dyes, which are capable of dyeing cotton fibers with a high yield [58]. This compound exhibits acceptable dyeing characteristics for natural fibers since the existence of four hydroxyl groups in its structure [58,59].

Red onion (Allium cepa L.) skins are an anthocyanin source that gives a red color. The principal anthocyanins existing in the skins of the red onion are pelargonidin, malvidin, and cyanidin [60]. The flavylium compounds can be used as textile dyes. It was revealed in some Indian communities in Central and South America [61]. Red onion includes mostly flavonoid compounds principally quercetin-rich and its derivatives. 1 kg onion (Allium ascalonicum) contains nearly 415-1917 mg in terms of ingredient of flavonoids. Onion skin compared to the insides of onion has more antioxidant properties. Its extract can be used as color giving mixture

relating to coloring substances in traditional foods [62].

Some Selected Studies

In 1896, Perkin and Hummel reported that the dye of onion skins is quercetin [63].

In a book published by Uğur in 1988, the colors produced from some plants mentioned below including onion skin were obtained.

For yellow colors

1 kg of onion skin, 500 grams of linden, and the same amount of sage plants are kept in cold water for 3 days. If the wool mordanted with alum is boiled in the same water for 1 hour, a bright chromatic color called lemon yellow is formed. If the wool mordanted with chrome is boiled in this water, coppery yellow tones are obtained. Onion skin, which is known to be low in fastness, varies according to the fastness of the other dyestuffs used together.

For red colors

Dried quince leaves with the skins of red onions are kept in water for a week. The quantities required for 1 kg of pre-mordanted (with alum) wool are taken as 500-700 grams per kilogram of wool. After boiling for 1 hour, bright peach red is obtained [64].

In a study published by Arlı et al. in 1993, it can be said that it would be appropriate to use vegetable dyes for certain colors and patterns in certain regions for hand-woven carpet dyeing [65].

In a study reported by Breu in 1996, it can be said that quercetin and its glycosides are present in skins of colored onions and skins of white onions. These compounds in the colored onion skins (2.5-6.5 g/100 g dry weight) were higher than present in skins of white onion (0.001 g/100 g). Apart from these, the presence of quercetin, quercetin-4'-glycoside, quercetin-7,4'-diglycoside, quercetin-3,4'-diglycoside, and kaempferol in onion skin (Allium cepa L.) was mentioned [66].

In a study reported by Önal in 1996, dyestuff extraction was performed from onion skin (Allium cepa) and at the same time, this extract was applied for coloring wool, feathered leather, and cotton. Otherwise, it was emphasized that onion skin is a waste product and it will be a commercial approach if it is aimed to obtain dyestuff [67].

According to a monograph reported in 1999, the quercetin flavonol compound was manufactured in Brazil, Germany, Japan, Spain, Switzerland, the United Kingdom, and the United States [68].

In a book published by Böhmer et al. in 2002, it can be said that if quercetin is just a dyestuff in, for example, onion skins (Allium cepa), a yellow dye based on this source will exactly discolor in sunlight within days or weeks. As a result of the addition of copper salt (1-2 % of the weight of the wool) to the alum mordant or later to the dyebath, the light-fastness relating to the yellow dye will be developed. The copper originating in the mordant will likely combine with quercetin to form an additional, relatively stable pigment. Most research has shown that light fastness can be largely enhanced when purely calcium salts are used as mordanting agents [69].

In a study reported by Vanker et al. in 2009, they scientifically utilized onion skin, a natural source of dye, to create the light brown and dark brown hues. It was stated that the use of color reaction products in the coloring of natural or synthetic fiber materials including nylon, wool, silk, kapok, polyesters, and the color reaction between metal ions of natural dyestuffs such as quercetin in onion skin was previously revealed. It can be said that onion skin has been used in wool dyeing by some workers [70].

In a study reported by Tezel in 2009, it was stated that Yazmacılık art is one of the traditional handicrafts in Anatolia. In the art of Yazmacılık, techniques and designs were examined. In addition, an application technique by a master from Kastamonu was given. Onion skin, buckthorn, and walnut leaves can be given as dye sources in obtaining natural dye used in Yazmacılık [71].

In a study reported by Önem et al. in 2012, it was revealed that the extract obtained from onion (Allium cepa L.) peel is used as a mixture including dyestuffs in the leather industry [1].

According to a study reported by Kavuncuoğlu in 2012, in an analysis realized by HPLC, 1.9 g/kg quercetin 4'-glycoside and 3.2 g/kg quercetin aglycone were determined in onion skins [72].

A study reported by Terra et al. in 2012, it was aimed to color wool, silk, and cotton samples for the conservation applications of the archaeological textiles. For this, the dye extracted from onion scales and five different mordants (alum, potassium dichromate, tin chloride, ferrous sulfate, and copper sulfate) were used. After the mordants were varied, different strong bright fast colors were achieved [73].

In a study reported in 2012, to collect and preserve the traditional information about dye plants and natural dyeing in the Southeastern Anatolia Region, it was revealed that the skins of the onion plant were used to obtain yellow color in natural dyeing. However, information on the usage of the peel of the plant in natural coloring in the study area was obtained in the regions of Uludere in Şırnak, Çukurca in Hakkari, Elbistan in Kahramanmaraş and Daren in Malatya. In addition, onion skins are used in egg dyeing throughout the region. A golden yellow color was obtained as a result of the wool, which was alum mordanted and dyed with onion skin. Natural dyeing with onion skin is among the traditional dyeing methods in the region [74].

In a study reported by Hatipoğlu in 2013, examples of flat weaving from the Damal district of Ardahan were given. Onion skin was used to obtain yellow and beige tones in the region. Only onion skin was used to obtain a colorful yellow. To obtain a tone close to the color of walnut shell, madder plant and onion skin were mixed [75].

One of the most important components of dye in red onion skin is quercetin dyestuff. In a study reported in 2013, the quercetin content was mentioned to be 391.60 mg. Also, pelargonidin content was 0.16 mg. These values were for 100 grams of dry weight [76].

In a study reported by Dias et al. in 2013, onion skins (Allium cepa L.) and alum mordant were used for the dyeing of wool samples. In the HCl extract of onion-dyed wool, quercetin dyestuff was identified. Also, in the onion skin dye bath and the EDTA/DMF extract of onion-dyed wool was determined quercetin-4'-O-glycoside and quercetin [77].

A study reported by Uddin in 2014 revealed that onion skin has the capacity to the coloring silk fabric [78].

In a study reported by Priyadharsini et al. in 2014, onion skin-one of the natural dye sources was extracted to obtain the dye. This dye then was analyzed with FT-IR spectroscopy. Quercetin, kaempferol, and quercetin-3-glycoside in the dye were characterized [79].

In a study reported by Güngörmez in 2015, the dyestuffs found in various plants and the colors obtained were mentioned in the chart. In this context, onion skin was a source of dyestuff, and the dyestuff in the onion skin was quercetin. It could be said that quercetin was a coloring agent. According to the chart, olive green, orange-yellow, and yellow colors could be produced [80].

In a study reported by Miah et al. in 2016, nylon fabric was dyed with onion skin, which is a natural dye source, using mordants like alum, copper sulfate, and potassium dichromate. The fastness values of the dyeings obtained in this study were good [81].

In a study reported by Seema in 2017, the use of onion skin, a waste natural product, for silk dyeing with minimal cost was investigated [82].

In a study reported by Karakelle in 2017, the colors obtained from some plants grown in Hatay were evaluated by subjective and objective methods in dyeing wool rug yarns. Colors obtained from these plants with onion skin and various mordants were also given. However, the colors of the dyeings were obtained in response to the use of aluminum alum (red-brown), tartaric acid (tan), potassium bichromate (dark red-brown), and sodium chloride (red soil) and tin chloride (dark orange) mordants were given. In addition, without mordant (light tan), only the color of dyeing with onion skin was revealed. The objective values of the colors provided for dyeing the wool rug fiber with the same mordants with onion skin are given in this study. The highest values in dyeing with onion skin were obtained with tin chloride mordant (L = 37.67, a = 30.50, b = 47.75, dE

= 35.76). For the dE value, the values of undyed wool are taken as the basis [83].

Onion is a cultivated vegetable product. Except for onion's outer skin, it is a product that can be eaten in terms of humans. The onion outer skin is normally a waste product. According to a study reported in 2018, the authors tried to produce a color variation on silk fabric with different mordant varieties of the outermost skin of the onion (Allium cepa). Three different mordanting techniques were applied in this study. Colorfastness properties relating to onion skin-colored materials were also analyzed in this study [84].

But, since this waste product contains natural dyes, it can be especially preferred in the dyeing working of fibers [45].

It is estimated that nearly 450,000 tons of onion waste yearly were produced in the European Union [76].

Onion skin-dyed fibers can economically be obtained from being a waste product [1].

These fibers can be obtained as an environmental friend. Naturally, if this dyeing is performed without non-toxic mordants, this is the desired dyeing. Onion was depicted more compared to other plants in terms of pictures present in Egypt graves. Onion outer skin including yellow dyes in many sources was also used in the Easter ceremonies of Christians. In the ceremonies, the coloring of eggs was aimed. The dye obtained from onion skin can be used to dye wool. In this dyeing, the different color tones can be produced using metallic mordants. Among these mordants, alum, copper sulfate, iron (II) sulfate, and stannous chloride can be given as a sample in the mordanting of natural fibers. Then, after the yellow onion skin is used to dye, it can be obtained that yellow from stannous chloride, orange yellow from alum, olive green from iron (II) sulfate, and khaki from copper sulfate [85].

In a study reported by Deveoğlu in 2018, quercetin was determined in onion-skin aqueous extract and onion-skin dyed silk extract (unmordanted silk) (37 % HCl /MeOH/H_2O (2:1:1; v/v/v)) with RP-HPLC-DAD [86].

In a study reported by Maryam et al. in 2019, the natural dye was obtained from onion skin (Allium cepa). However, cotton fabrics were dyed with this dye. The mordants used were alum, copper sulfate, iron sulfate, tannin acid, aloe vera, and lemon juice. As natural mordants produced a faded color, synthetic mordants presented a yellow color [87].

In a study reported by Yıldırım et al. in 2019, the plants (Antalya-Turkey) used for dyeing Karaöz (Aksu-Antalya) carpet yarns were examined. Olive green color was provided from onion (Allium cepa L.) [88].

In a study reported by Keşmer et al. in 2020, red pine bark (Pinus brutia) and onion skin (Allium cepa) were used in the dyeing of paper pulp. The paper pulp with the obtained dyes was dyed with mordant and mordant-free. Alum as a mordant was selected. The spectroscopic analyses were also realized [89].

In a study reported by Nguyen and Bechtold in 2021, onion skin-based aluminum lake pigment was obtained. In this study, the air-dried onion skin (2.1 kg) and $Al_2(SO_4)_3.14\text{-}15H_2O$ (200 g) were used to produce the lake pigment. Finally, the dried aluminum lake (199.12 g) was generated [90].

In a study reported by Botteri et al. in 2022, the influence of cotton pre-treatment on dyeing with onion and pomegranate peel extracts was investigated [91].

Conclusions

In this study, the dyeing property of onion skin and the dyestuffs in onion skin are given. Obtaining dye from onion skin is an environmentally friendly process and beneficial for sustainability. The use of onion skin, which is a natural waste product, in the field of natural dyeing and its high content of dyestuffs brings with it a situation that needs to be concentrated. The outer skin of the onion plant is rich in quercetin. In dyeings made with quercetin flavonols, they can add antioxidant properties to the dyed fiber. With the production of lakes from onion plant wastes, it is possible to obtain pigments that can be used in various areas economically.

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دراسة مراجعية على قشرة البصل ، مصدر صبغة طبيعية

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الملخص
قشر نبات البصل هو نفايات طبيعية من الممكن تقييم استخدامها في الصباغة الطبيعية (القطن ، الصوف ، الحرير ، إلخ) وفي إنتاج أصباغ البحيرة عن طريق استخراج الصبغات في هذه النفايات .يحتوي الجلد الذي يشكل هذا الجزء الخارجي على بعض الأصباغ الطبيعية من الفلافونويد (كيرسيتين ، إلخ) وأنثوسيانيدين (بيلارجونيدين ، إلخ .(كيرسيتين جليكوسيدات هي مركبات الفلافونويد المسؤولة عن غالبية مركبات الفلافونول في النبات .قد تزيد كمية الكيرسيتين من الجزء الداخلي من نبات البصل إلى الجزء الخارجي .من المعروف أن قشر البصل قد استخدم في صبغ الصوف من الماضي إلى الحاضر .تم استخدامه تقليديا في السجاد والبسط .تم استخدام قشر البصل في الأناضول ، تركيا ، حيث تم إنتاج السجاد والبسط.