Advanced Materials Science and Technology; 2022 Vol 4 Issue 1
www.omniscient.sg

Review

Open Access

Omniscient Pte.Ltd.

Types and Application Progress of Tobacco Moistening Agents

Feng Xu[1], Zhongpan Hu[2], Jianzhong Zhang[1], Hongyu Ye[1], Ruoxin Wu[1]*

[1]Tianjin Workstation, Technology Center of Shanghai Tobacco Group Co., Ltd, Tianjin 300163, China.
[2]National Institute for Advanced Materials, School of Materials Science and Engineering, Nankai University, Tianjin 300350, China.

***Correspondence to:** Ruoxin Wu, Tianjin Workstation, Technology Center of Shanghai Tobacco Group Co., Ltd, Tianjin 300163, China; Email: wuruoxin0305@163.com

DOI: 10.37155/2717-526X-0401-6

Abstract: Tobacco moistening technology is an important direction of research in the tobacco industry and a key technology to improve tobacco quality and enhance the core competitiveness of cigarettes. The main goal of tobacco moistening is to solve the problems of rapid moisture loss, pungent, dry and harsh tobacco smoke, and thus improve the smoking comfort of tobacco products. Moreover, improving the moistening performance of tobacco can also increase the flexibility of tobacco and reduce fragmentation. The paper summarizes the factors affecting the moistening performance of tobacco, the moistening mechanism of moistening agents and the types of moistening agents, discusses the characteristics and advantages of different moistening agents in detail, and provides a reasonable outlook on the development direction of moistening technology.
Keywords: Tobacco moistening; Moistening agent; Moisture absorption; Sensory quality; Smoking perception

1. Introduction

With the development of social economy and the improvement of people's living standards, consumers have higher requirements for the quality of tobacco products, from the simple pursuit of physiological satisfaction to the pursuit of comfort, which has also put forward higher requirements for the tobacco industry. Among them, tobacco moistening has become a hot spot of tobacco industry research. The moistening properties of tobacco can greatly affect the aroma and taste of tobacco, so improving the moistening properties of tobacco has become a significant indicator to enhance the taste of tobacco[1,2]. In addition, during the cigarette rolling process, the variation of tobacco moisture has a great impact on the cutting process, because the dehydrated tobacco with a high fragmentation rate is easily broken, and the processability will be greatly reduced[3,4]. Therefore, how to improve the moistening performance of tobacco, reduce the evaporation of tobacco moisture, and improve the sensory comfort of tobacco products has become the focus of attention in the tobacco

© The Author(s) 2022. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, sharing, adaptation, distribution and reproduction in any medium or format, for any purpose, even commercially, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

industry and an important technology to improve the quality of tobacco products.

Tobacco moist retention performance refers to the ability of tobacco to inhibit moisture dissipation in a low humidity environment. At present, in the cigarette rolling process, in order to preserve the moisture within the tobacco, moistening agents are generally added to the cigarette rolling process as needed (except for some high-grade cigarettes). The addition of these moistening agents can effectively improve the physical and chemical properties, improve the moisture-absorbing properties of tobacco, and achieve the purpose of preserving moisture. The main common moistening agents are propylene glycol, diethylene glycol, butylene glycol, xylitol, sorbitol, glycerol, and some natural products or extracts. These moistening agents contain a large number of hydroxyl and carboxyl groups, which are able to form hydrogen bonds with water molecules to retain water[5,6]. In addition, some moistening agents are able to form a three-dimensional network structure on the surface of tobacco, thus preventing water dissipation and achieving the purpose of wetting retention.

In recent years, a large number of researchers have found that some composite types of moistening agents are significantly better than single type of moistening agents. Some new composite moisturizers have been developed to replace traditional moisturizers, such as chitosan derivatives, D-galacturonic acid, maltose oligosaccharide, tea tree mushroom polysaccharide, bionic moisturizer (FSB), PDS, PCA, NCS, *etc.*[5-8]. These new moistening agents can not only effectively improve the moisturizing effect of tobacco, but also reduce the production of harmful substances during the combustion of tobacco, which has become a hot spot for current research. In addition, how to evaluate the advantages and disadvantages of the moistening agent and analyze the composition of the moistening agent is also an important research direction in the tobacco industry. With the development of modern analytical instruments, the analysis methods of tobacco moistening agent composition have been greatly expanded, and the efficiency and accuracy of detection have been significantly improved.

2. The Main Factors Affecting the Moistening Performance of Cigarettes

Tobacco is an important raw material for the production of cigarette products, and its main chemical components include sugars, nitrogenous compounds, alkaloids, organic acids, phenols, pigments, lipids, and water and minerals[9]. Depending on the origin, the main components of tobacco vary slightly. In addition, for different varieties, grades, and parts of tobacco products, the physical structure and chemical composition are different, and there are some differences in the moist retention properties. The main factors affecting the moist retention properties of tobacco can be classified according to the influence of the physical structure and chemical composition of tobacco.

2.1 Effect of physical structure of tobacco

Tobacco is a porous material, and its microstructure such as specific surface area and pore volume has a great influence on the moist retention properties of tobacco. The reason is that tobacco surface contains a large number of capillaries, these capillaries not only affect the diffusion of water inside the tobacco, but also affect the condensation of water inside the tobacco. In addition, the specific surface area of tobacco leaves also has a certain influence on the moistening performance of tobacco, too large a specific surface area may lead to rapid water dissipation and poor moistening properties.

Smejima *et al.*[10] investigated the process of water transfer in tobacco and found that tobacco leaves mainly absorbed water through the upper and lower epidermis, while cut tobacco less than 1 mm-wide absorbed water mainly through the cut surface. Lou *et al.*[11] investigated the physical moisture retention properties of different cigarette raw materials and explained the differences in the moisture retention properties of different cigarette products from a mechanistic point of view. At 25.2 ^{o}C and 3.0 kPa, the adsorption of water molecules by different parts of the tobacco was: leaf > expanded leaf > expanded stem > slice, and the initial adsorption enthalpy was calculated by fitting the Sips model as expanded stem > expanded leaf > leaf > slice. This is due to the large internal pores of the stem, which exhibit rapid moisture absorption and desorption with changes in ambient humidity, while the leaf have the best moist retention performance because of their rich oil content.

In addition, there is also a correlation between the color of tobacco and its moistening properties.

Mckee *et al*.[12] analyzed Maryland tobacco harvested in different years and found that light-colored tobacco had better moistening properties than dark-colored tobacco. Bacot *et al*.[13] analyzed tobacco of the same grade and reached the same conclusion. In order to understand the moistening mechanism of tobacco, many researchers have done a lot of work, which also provides theoretical and practical guidance for tobacco moistening. In addition, it has also been shown that the differences in tobacco moistening properties are not only related to the physical properties of tobacco itself, but also to the cultivation, roasting, and manufacturing process.

2.2 Effect of tobacco chemical composition

The chemical composition of the tobacco also has a significant impact on the tobacco moist retention properties. Compositionally, tobacco contains a large number of gum compounds (pectins, sugars and organic salts, *etc*.), which can effectively fix the water inside the tobacco and thus achieve moist retention[14]. In general, tobacco leaves with high sugar content also have better moist retention properties. This is due to the fact that sugars contain a large number of hydroxyl and carboxyl species, which can form a large number of intermolecular hydrogen bonds with water molecules, thus preventing the escape of water and achieving the purpose of moist retention.

Xu *et al*.[15] studied the relationship between water-soluble sugars, aroma-causing components and organic acids and tobacco moistening properties, and the results showed that fructose, glucose and phenylacetic acid were positively correlated with tobacco moistening properties, and some aroma-causing components (2-phenylfuran, 2-pyridinecarboxaldehyde, 1-(1H-pyrrole-2-)-ethanone and 2-methylpropionic acid) were also beneficial to improving tobacco moistening properties. It has also been shown that the crude fiber content of tobacco leaves, total chlorine content, etc. have a role in improving the moist retention properties of tobacco[16,17].

During the manufacturing process of tobacco, there are some changes in chemical composition, which lead to changes in tobacco moistening properties. In general, during the roasting process, the starch within the original tobacco leaves decreases and gradually changes to reducing sugars and organic acids, etc. The nitrogen content, pH and sugar content of tobacco leaves will be decreased in some amount during the aging process. Wang *et al*.[18] studied the aging characteristics of roasted tobacco in Hechi, Guangxi, and found that after 12 months of aging treatment, the nitrogen content and nicotine content of tobacco generally increased, the sugar content generally decreased, and the sugar-base ratio generally decreased. Hu *et al*.[19] investigated the changes of physical and chemical indexes of B2F and C3F in Henan re-roasted tobacco, and found that with the increase of aging time, neutral aroma components and aldehydes of C3F and B2F showed an increasing trend, and alcohols, ketones and carbonyl compounds showed a decreasing trend. Wang *et al*.[20] studied the changes in the transfer of water molecules in tobacco using isotope tracing and determined the amount and point of loss of water in the entire tobacco manufacturing process. Almost all of the water loss in the tobacco manufacturing process was concentrated in the frying process.

In addition, the aging process of tobacco has also changed the fatty acids[21], organic acids[22], and polyphenols[23] within the tobacco, and these components also have a very obvious effect on the moist retention properties of tobacco. After aging, the moisture of tobacco leaves decreases more significantly and needs to be loosened and rewetted, then premixed, spiked, stored in leaves, cut, roasted and expanded, and finally made into finished tobacco. Studies have shown that some chemical components in tobacco, such as phenols, alcohols, ketones, and sugars, will change in amount during the manufacturing process[24]. And the changes in these chemical components such as sugars and cellulose have a great impact on the moist retention properties of tobacco.

As mentioned above, the physical structure and chemical composition of tobacco are important factors affecting the moistening performance of tobacco. Therefore, studying the changes of microstructure and chemical composition of tobacco can provide some theoretical basis for tobacco moistening technology.

3. Moistening Mechanism

Tobacco water retention properties consist of two main aspects, the thermodynamic aspect of the equilibrium water content of the cigarette and the kinetic aspect of the rate of water loss from the

cigarette[25,26]. In cigarettes, improving equilibrium water is generally done by adding moistening agents to reduce the chemical potential energy of water within the tobacco. The capillary water adsorption of tobacco can also be increased by increasing the porosity of the tobacco leaves[8]. However, kinetic water loss is difficult to control and, in general, the higher the equilibrium moisture, the faster the rate of water loss[10]. The tobacco industry mainly aims to improve the moist retention properties of tobacco by adding moistening agents to tobacco products.

At present, the research on tobacco moistening agents is focused on polyhydroxy compounds such as propylene glycol, propanetriol, sorbitol, sugars, proteins, organic salts (potassium lactate, sodium lactate, potassium acetate, *etc*.), maltose oligosaccharide alcohols, chitosan derivatives, *etc*.[27,28]. Their main role is to retain the moisture inside the tobacco, increase the flexibility and workability of the tobacco, reduce shattering, and improve the smoking comfort of tobacco products. Tobacco moistening agents are classified into hygroscopic moistening agents, hydrating moistening agents and blocking moistening agents in terms of molecular structure, and the moistening mechanism of these different moistening agents varies. **Table 1** lists the types of moistening mechanism and the principle of action of different moistening agents.

Table 1 Mechanistic types and principles of action of different moistening agents

Moistening agent	Mechanism type	Principle of action	Reference
6-O-Carboxymethyl-D-galactopyranose	hygroscopic	Hydrogen bonding between hydroxyl groups and water in the moisturizer	[6]
Luo Han Guo	hygroscopic	The interaction of glycosidic polysaccharide molecular chains and water molecules form hydrogen bonds	[29]
Halo-Diglyceride polysaccharide	hygroscopic	The polysaccharide molecule of Halodiopsis contains a large number of carboxyl groups and water molecules to form a large number of hydrogen bonds	[30]
Flavopiridol polysaccharide	hygroscopic	Hydroxyl groups in the polysaccharide molecules of Flavobacterium flavum form hydrogen bonds with water molecules	[31,32]
Gum Arabic	hygroscopic	Intermolecular forces (hydrogen bonds formed between molecules)	[33]
Ganoderma lucidum polysaccharide	hygroscopic	Polysaccharide samples contain a large number of carboxyl and hydroxyl groups and water molecules to form hydrogen bonds between them	[34]
Konjac glucomannan	hygroscopic、blocking	Hydroxyl and carboxyl groups form hydrogen bonds; the moistening agent also has good film-forming properties, forming a stable closed film on the surface of tobacco, preventing the escape of water molecules	[35,36]
Konjac glucomannan derivatives	hygroscopic、blocking	Hydroxyl and carboxyl groups form a large number of hydrogen bonds with water; a three-dimensional network structure is formed on the surface of tobacco to prevent the escape of water molecules	[37]
Emulsified corn oil	hygroscopic、blocking	Hydroxyl and carboxyl groups form a large number of hydrogen bonds with water; form a stable closed film on the surface of tobacco	[38]
Aloe polysaccharide	hygroscopic	Hydrogen bonds are formed between hydroxyl groups and water molecules	[39]
Potassium L-2-pyrrolidone-5-carboxylate	hygroscopic	Moistening agent and water molecules form hydrogen bonds to prevent the dispersion of water molecules	[40]
1-O-carboxymethyl-D-ribofuranomannose(V)	hygroscopic	Hydrogen bonds formed between molecules containing a large number of carboxyl groups and water	[41]
1-O-carboxyethyl-D-ribofuranomannose(VII)	hygroscopic	Contains a large number of hydrogen bonds formed between carboxyl groups and water molecules	[41]
Grapefruit peel polysaccharide	hygroscopic、blocking	Containing hydroxyl groups and water forming hydrogen bonds; forming a three-dimensional spatial network structure on the surface of tobacco, preventing water molecules from escaping	[42]
Cactus polysaccharide	hygroscopic、blocking	Hydrogen bonds formed between hydroxyl and carboxyl groups and water molecules, and cross-linked to form a network structure	[43]

Continuation Table:

Moistening agent	Mechanism type	Principle of action	Reference
KSAP-T	hygroscopic、blocking	Contains a large number of hydrophilic groups and three-dimensional spatial network structure	[44]
RSN-E	hygroscopic	The molecule contains a large number of carboxyl groups, hydroxyl groups and other polar groups and water molecules to form a large number of hydrogen bonds	[45]
Lactic acid and potassium lactate	hygroscopic	Multi-hydroxyl type moistening agent, can form hydrogen bonds with water molecules	[46]
Loofah polysaccharide	hygroscopic	Multi-hydroxyl class moistening agent, can form hydrogen bonds with water molecules	[47]
Taro polysaccharide	hygroscopic	Multi-hydroxyl class moistening agent, can form hydrogen bonds with water molecules or trap moisture in the air	[48]

The moistening mechanism of hygroscopic moistening agents (such as polyol compounds) is that the polyol is adsorbed into the molecular layer or capillary condensation water phase, which effectively reduces the chemical potential energy of water, in favor of increasing the amount of water adsorption. Meanwhile, the polyhydroxy compounds can effectively prevent the reduction of capillary condensation tubes and increase the equilibrium water content. Huang *et al.*[30] and Cui *et al.*[49] suggested that the hydroxyl group in the retaining agent can form hydrogen bonds with water molecules, and thus has a certain moisturizing effect. Zhang *et al.*[50] compared the moisturizing effect of honey, glucose, fructose, maltose, and propylene glycol, and found that honey was the strongest, propylene glycol was the second strongest, and distilled water was the worst. The performance of composite moistening agents showed that honey-propylene glycol was the best, honey-propylene glycol-glucose was the second best, and distilled water was the worst. Some other moistening agents have both hygroscopic and moisture-repellent effects, such as Arabic gum[33], Ganoderma lucidum polysaccharide[34], konjac glucomannan[35,37], and copper algae polysaccharide[51].

Hydrating moistening agents (magnesium salt, aluminum salt, *etc.*) contain some metal ions, which mainly form compounds containing crystal water in tobacco leaves after solvation with water molecules to achieve the purpose of moisture retention.

Blocking moistening agents (vegetable oils[38], paraffin oils, natural oily extracts, *etc.*) form a sealing barrier in tobacco products to prevent internal moisture evaporation.

4. Cigarette Moistening Agent Types

Currently, the moistening properties of cigarette products are mainly improved by adding moistening agents in the tobacco industry. The common tobacco moistening agents are mainly polyhydroxy compounds such as propylene glycol, propanetriol, and sorbitol[52]. In recent years, many new moistening agents have been developed, including plant polysaccharides and some natural extracts.

4.1 Polyol moistening agents

Polyol moistening agents are the most widely used moistening agents in the tobacco process, such as sorbitol, propylene glycol, propanetriol, butylene glycol, etc. Because of their low price and wide availability, these moistening agents are widely used in the cigarette process. Guo *et al.*[39] studied the effects of four polyols, namely, propylene glycol, propanetriol, xylitol and sorbitol, on tobacco indicating the void texture structure and moisture absorption characteristics, and found that these polyols significantly increased the water content of tobacco. The addition of polyols makes the guard cells of stomata on the leaf surface expand to a certain extent, thus enhancing the water holding capacity of tobacco.

Wang *et al.*[40] added propylene glycol and potassium L-2-pyrrolidone-5-carboxylate (PCA-K) to tobacco, respectively, and explored their water retention effects; both substances increased the water content of the tobacco when added to the tobacco. The water retention agent was absorbed by the tobacco to form more hydrogen bonds, and when water molecules amount in the tobacco is low, the water retention agent absorbs water from the external environment for the formation of chemical bonds, thus increasing the water content of the tobacco filaments. Yi *et al.*[53] compared the differences and characteristics of propylene glycol

and several other moistening agents, and found that the two hydroxyl groups in the propylene glycol molecule can form hydrogen bonds with water molecules, and has better inter-solubility with spices and better moistening effect with certain hygroscopic properties. Liu *et al*.[54] investigated the effect of different types of moistening agents (propylene glycol, glycerol, xylitol, sorbitol, *etc*.) on the chemical composition of cigarette smoke, and found that the addition of different types of moistening agents had a significant effect on the chemical composition of cigarette smoke and changed with the addition amount. Besides, the addition of moistening agents would increase the aroma-causing components and benzene and amine compounds in cigarette smoke.

Although these polyol moistening agents can effectively preserve the water content of tobacco to a certain extent, and improve the flexibility of the tobacco. However, the problems such as pungency, dryness and fragrance produced in the smoking process of cigarette products have not been greatly improved. It is a challenge for the tobacco industry to develop multifunctional tobacco humectants.

4.2 Natural extracts

Due to the inherent defects of traditional moistening agents, many new types of moistening agents are gradually developed, among which, natural plant, animal and microbial derived sugars and polyester compounds are developed and applied to the tobacco wetting process, and these new moistening agents show unique advantages in improving tobacco flavor and sensory comfort.

Among them, natural plant polysaccharide extracts and alcohol compounds are similar in that they contain a large number of intramolecular hydroxyl groups, which can form chemical bonds between them and water molecules, thus achieving the purpose of retaining moisture. At the same time, the sugars themselves can effectively harmonize the eating flavor of the smoke, reduce the irritating and pungent taste, improve the aftertaste and make the senses comfortable, and are also a key technology for spicing and flavoring tobacco. At present, common sugars mainly include glucose, sucrose, fructose, lactose, caramel, xylose, maltose and honey, as well as some sugar alcohol compounds (sorbitol, mannitol, maltitol, xylitol, *etc*.).

A large number of researches has been studied of the effects of different sugar compounds on tobacco moistening, smoke composition, and aroma components. Huang *et al*.[30] used ultrasonic extraction process to extract halofugose polysaccharide and investigated the effect of this substance on the moistening performance of tobacco and the sensory comfort of cigarette. Halofugose polysaccharide is a sugar compound containing a large number of surface hydroxyl groups, so it can effectively slow down the water loss of tobacco and can improve the eating flavor of tobacco. Lu *et al*.[34] extracted Ganoderma lucidum polysaccharide GLP from Ganoderma lucidum, prepared the carboxymethylated product CM-GLP, and studied its moist retention properties under different conditions. The moist retention properties of this substance were better than propylene glycol and glycerol under low humidity environment. In addition, this polysaccharide compound could make cigarette smoke softer, rounder, less irritating, and improve the smoking comfort of tobacco. Yan *et al*.[35] and Cheng *et al*.[37] studied the role of konjac glucosamine-based compounds in tobacco moist retention and studied the hydrophilic groups (carboxyl, hydroxyl, amide groups, *etc*.) on its surface using infrared spectroscopy. The molecule is rich in hydrophilic groups, it can thus form a large number of hydrogen bonds with water and hinder the escape of water molecules, while the hydrophobic groups are easily folded inward, forming a locally insoluble At the same time, the hydrophobic groups are easily folded to the inner side to form a local insoluble particle structure, which makes the water molecules entering the grid inactive and achieves the effect of moisture retention. Chen *et al*.[41] used D-mannose (I) to synthesize 1-O-carboxymethyl-D-furanomannose (V) and 1-O-carboxyethyl-D-mannopyranose(VII), both of which have obvious moistening properties and can make cigarette smoke more rounded and softer, reduce irritation and impurities, and enhance taste comfort. Guo *et al*.[42] extracted grapefruit peel polysaccharide and applied it to six kinds of tobacco for moistening test, and the moistening effect of these different kinds of tobacco was different, among which grapefruit peel polysaccharide had the best moistening effect on B3F and relatively poor moistening effect on B1F. Liu *et al*.[43] extracted cactus polysaccharide and applied it to

cigarette process. This polysaccharide can improve the moistening performance of tobacco, and also increase the amount of aroma of tobacco, improve the fineness and sweetness of the smoke. Chi *et al.*[44] used natural plant extracts such as aloe vera and cactus to develop the moisturizer CNY-J and compared it with the commonly used moisturizer propylene glycol. The test showed that the addition of this moisturizer could not only improve the moisturizing properties of tobacco, but also improve the irritation of the smoke, and improve the softness and fineness of the smoke.

Polysaccharide moistening agents contain a large number of hydroxyl functional groups, their moistening mechanism and polyol compounds are similar, but polysaccharide compounds have the irreplaceable advantages of polyols. Polysaccharide compounds not only have moisturizing effect, but also can reduce the intensity of flue gas, reduce the irritation and bitter taste of flue gas. If the dosage is appropriate, it can play a good role in promoting the aroma of cigarette, especially suitable for tobacco with low sugar content, high nitrogen compounds and nicotine content, and high pH of smoke. Therefore, the development of polysaccharide moistening agents is an important development direction for the future tobacco moistening industry.

Table 2 lists the applications of natural product extracts in tobacco processes for tobacco moisturization in recent years. Tan[33] added Arabic gum to tobacco and explored its moisturizing properties. Since gum is a colloidal substance, it can effectively fix water and thus showed excellent moisturizing effect in tobacco moisturizing, and this compound had no effect on the sensory quality of cigarette products. Guo *et al.*[45] synthesized konjac dextran-acrylic acid graft copolymer (KSAP) by modifying konjac dextran with acrylic acid graft copolymer, which contains a large number of hydrophilic groups such as hydroxyl and carboxyl groups and exhibits very good moisture absorption and moist retention properties, and the compound has no obvious side effects on the sensory of cigarette smoke, which has a very promising application. Yang *et al.*[46] developed an RSN-E moistening agent based on plants and fresh fruits, which is significantly better than the traditional propylene glycol moistening agent in terms of moisture retention, and the moistening agent can also improve the eating flavor of tobacco and reduce the pungency and dryness of the smoke; electron microscopy tests found that the moistening agent can change the surface structure of tobacco leaves, form a more dense protective film on the surface of tobacco leaves, and pores of tobacco leaves to The electron microscope test found that the moistening agent could change the surface structure of tobacco leaves, forming a dense protective film on the surface of tobacco leaves and blocking the pores of tobacco leaves to prevent the evaporation of internal moisture. Lou *et al.*[38] prepared highly concentrated corn oil by emulsification technology and added it to tobacco products to study its moisturizing properties. The results showed that the moisturizer was better than propylene glycol, and the sensory evaluation of cigarette products with corn oil was significantly better than those with propylene glycol.

Table 2 Application of different natural extracts in tobacco moisturizing

Moistening agent	Source	Humidity (%)	Addition (%)	Test time (h)	Water content (%)	Reference
Halothane polysaccharide	Halophyllum	40	5	40	9.28	[30]
Gum Arabic	Gum Arabic	40	0.15	48	17.4	[33]
Ganoderma lucidum polysaccharide	Ganoderma lucidum	40	0.15	48	> 8.0	[34]
Konjac glucomannan	Konjac	40	1	3.3	12.95	[35]
Konjac glucomannan	Konjac	40	0.5	24	10.05	[37]
Copper algae polysaccharide	Copper Algae	40	0.1	48	-	[51]
Corn oil	Corn	60	2	48	-	[38]
Grapefruit peel polysaccharide	Grapefruit Peel	50	2	6	-	[42]
Cactus polysaccharide	Cactus	40	1	250	-	[43]
CNY-J	Aloe vera, cactus, etc.	35	0.4	48	-	[44]
KSAP	Konjac	40	0.2	48	7.51	[45]
RSN-E	Plants and fresh fruits	40	0.5	11	8.79	[46]

In addition to plant-derived moistening agents, a small number of animal-derived and microbial-derived moistening agents have been developed, but in general these two types of moistening agents are less reported. However, animal and microbial as two rich resource pools also have a very large potential exploitation value. The role and effects of animal waxes, natural propolis, fungal polysaccharides, Cordyceps polysaccharides, and Ganoderma polysaccharides on tobacco moisturization have also been reported in the literature. Lai *et al.*[55] synthesized a wax ester tobacco moisturizer consisting of wax, emulsifier and water, where the wax can be plant wax, petroleum wax or animal wax, and the moisturizer has two main characteristics of moisture and moisture resistance, and is non-toxic and harmless after burning. Liu *et al.*[56] selected propolis extract for tobacco moisturization, and its moisturizing effect exceeded that of traditional moisturizers such as propylene glycol, propanetriol, and sorbitol, and the moisturizer can effectively remove free radicals from tobacco and improve the smoking safety of tobacco products. In recent years, research on the use of fungal polysaccharides as tobacco moisturizers has also emerged. Xu *et al.*[57] prepared a new tobacco flavoring using natural shiitake mushrooms as raw material by different methods, which not only increased the aroma of tobacco products, but also had moisturizing properties. Yang *et al.*[51] investigated the extraction process of copper algae polysaccharide and its effect on the moistening properties of tobacco. The results showed that copper algae polysaccharide can effectively reduce the water loss of tobacco under low humidity conditions and slow down the excessive absorption of water by tobacco under high humidity conditions, which has very excellent moistening and moisture retention effects.

Natural extracts have a wide range of sources, cheap and environmentally friendly, and thus have a very large potential use value. At the same time, natural products have multi-functional, not only can achieve tobacco moistening and can effectively improve the taste of tobacco, and even to enhance the flavor, reduce the effect of harm, has a great application prospects, but also is a very important direction for the development of tobacco moistening technology.

4.3 Organic salts

Organic salts compounds, such as potassium citrate, sodium citrate, potassium lactate, and sodium lactate, contain both hydroxyl and alkali metal ions, and thus have both moistening and combustion-assisting functions[58-60]. Zhou *et al.*[59] studied the effect of lactic acid and lactate on the moistening properties of tobacco and showed excellent tobacco moistening properties because lactic acid is a polyhydroxy compound. In addition, this lactate moisturizing agent showed great advantages in enhancing the sensory comfort of cigarette products. Bai *et al.*[60] investigated the role of complexes with organic acids as ligands and Fe(III), Mn(II), Zn(II), and Ce(II) as central ions in cigarette products, and found that these complexes have multiple functions, not only in terms of their ability to aid in the combustion and catalytic oxidation of CO, but also in terms of tobacco moist retention. Yin *et al.*[61] systematically studied the moistening properties of potassium lactate on tobacco products, and found that potassium lactate could effectively improve the moistening properties of cigarettes, but also affect the sensory quality of tobacco products. It was found that potassium lactate had no effect on the total particulate matter, nicotine, tar, puff count and volatile carbonyl compounds in the mainstream cigarette smoke, but significantly increased the moisture content and decreased the pH of the smoke.

4.4 Others

In addition to the above-mentioned moistening agents, some bionic and wax ester moistening agents have been developed, and tobacco itself also has certain moistening properties. Ma *et al.*[14] studied the effect of the physical structure and chemical composition of tobacco on the moisture retention of tobacco, and because the surface structure and chemical composition of different tobaccos are different, thus their moisture retention properties are also different and their moisture retention capacity also differs. Ai *et al.*[62] developed a new bionic tobacco moistener, which can form a bionic film on the surface of the tobacco to organize the evaporation of water inside the tobacco and achieve the purpose of moist retention. In addition, Chen *et al.*[63] investigated the role of a bidirectional moisturizer(natural pentosan) in tobacco moisturization, which can achieve moisturization in

low humidity environments and moisture resistance in high humidity environments, and slow release of aroma-causing components to improve the sensory quality of cigarette smoke. Some selective adsorbent materials in the filter segments[64] are not able to improve the moistening properties of tobacco, but they are good for improving the dryness of the draw, reducing irritation, and improving the aftertaste.

Overall, the development of tobacco moistening agents has gone through several important stages, from the earlier polyols, to the later transformation of polysaccharides, natural extracts, organic salts compounds. From the pursuit of moistening performance only, to both moistening and sensory quality.

5. Outlook

Tobacco moistening is an important technology to increase the flexibility of tobacco, reduce shattering and improve the sensory comfort of tobacco, and it is also an important direction for the future development of the tobacco industry. At present, the research on tobacco moistening technology mainly focuses on the factors affecting tobacco moistening, the investigation of moistening mechanism and the development of moistening agents, among which, the development of moistening agents is the hot spot of tobacco workers in recent years. The moisturizing agent is mainly divided into alcohols, polysaccharides, natural extracts and so on, of which natural extracts with good moisturizing effect, and at the same time with moisture, aroma and other characteristics have been widely concerned, and is considered the main direction of the future development of tobacco moisturizing agent.

Although tobacco moistening technology has become increasingly mature, a large number of efficient moistening agents have been developed, but the preparation of moisture absorption, sealing, hydration and composite moistening agent is still a huge challenge, the search for new technology and technology and the scale of production of composite moistening agent to reduce costs and increase efficiency of tobacco products is a pressing problem in the tobacco industry. The application process of the rinse retention agent is also one of the important factors affecting the rinse retention effect. The author examined the effect of the leaf filament dosing process[65] on the dosing effect, which can effectively improve the effective utilization rate and uniformity of the material solution and has a positive effect on the effect of the rinse retention agent, and the dosing equipment and dosing process are also the direction that tobacco workers need to further optimize in order to improve the tobacco rinse retention effect at a later stage.

In addition, tobacco researchers should actively broaden the scope of research on moistening agents, focusing on the development of moistening agents, moisture resistance, aroma and sensory comfort and other multi-effects of moistening agents. We should conduct research on the extraction, purification and moistening properties of natural active ingredients, and synthesize or modify natural extracts with promising applications to develop new environmentally friendly moisturizers. In addition, the development and application of the detection method for moistening agents should be strengthened, and the author conducted a relevant study on the detection method for flavoring and fragrance[66,67], which is used to clarify the aroma composition and moistening effect of cigarettes and improve the quality of cigarettes by detecting the components that play a role in flavoring, fragrance enhancement and moistening in cigarettes. However, there are fewer reports on the detection of single wetting agent content, and further in-depth studies are still needed.

In recent years, the research in the field of tobacco moistening has continued to deepen and intensify, and a series of fruitful results have been achieved, and tobacco moistening technology will also usher in rapid and significant development.

Declaration of competing interest:

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

Acknowledgements

This work was primarily supported by Tianjin R&D Center, Shanghai Tobacco Group Co., Ltd. And a research from Shanghai Tobacco Group Co., Ltd (Grant No. K2020-2-003P, Research on the process technology

and application of different traits of cut stem).

References

[1] Zhang, A. F., Liu, C. B., Shan, S. Y., et al. Research progress on the moistening retention of tobacco. Light Industry Science and Technology, 2016(01): 56-58.

[2] Wang, H. Analysis of tobacco wetting agents. Light Industry Science and Technology, 2013(4): 5-6.

[3] Shang, S. Z., Lei, P., Wang, K. M., et al. Research progress of cigarette moistening technology. Applied Chemical Industry, 2014, 43(3): 535-538.

[4] Sun, W., Li, X. M., Zeng, X. Y., et al. The effect of tobacco water content on cigarette smoking quality, smoke moisture and volatile components of particle phase. Tobacco Science and Technology, 2009(11): 33-39.

[5] Ge, S. L., Shu, J. S., Xu, Z. Q., et al. Research progress on the application of chitosan and its derivatives on tobacco. Guangzhou Chemical Industry, 2009, 37(6): 30-32.

[6] Chen, Z. F., Sun, Z. T., Lu, C. T., et al. Synthesis and application of 6-O-carboxymethyl-D-galactopyranose. Tobacco Science & Technology, 2012(12): 52-55.

[7] Xing, Z. Z. Study on the use of tea tree mushroom polysaccharide as a moisturizing agent for tobacco, Yunnan University, 2014.

[8] Zhang, L. Study on the moistening properties of cigarette and its application technology. Hunan Agricultural University, 2012.

[9] Yin, J. Research on systematic identification and analysis of chemical composition of tobacco and products. Hunan University, 2001.

[10] Samejima, T., Nishikata, Y., Yano, T. Moisture permeability of cured tobacco epidermis. Agriculture and Biological Chemistry, 1984, 48(2): 439-443.

[11] Lou, J. Y., Zhang, Q., Wang, B., et al. Study on the physical moistening mechanism of different cigarette raw materials. Chinese Journal of Tobacco, 2014, 20(6): 49-55.

[12] Mckee, C. G., Frey, C. B., Hoyert, J. H. Effect of leaf moisture content on farm storage ability of Maryland tobacco packed in bales. Tobacco International, 1984(186): 114-117.

[13] Bacot, A. M. The chemical composition of representative grades of the 1952 and 1954 crops of flue-cured tobacco, Including Chemical Methods M. Washington: U.S. Government Printing Office, 1960.

[14] Ma, L., Zhou, B. Self-moistening properties of tobacco. Guangdong Chemistry, 2009, 36(10): 93-94.

[15] Xu, A. T., Wang, C. Study on the interrelationship between organic acids and water-soluble sugars in tobacco leaves and their moistening properties C. China Tobacco Innovation Forum, 2007.

[16] Mu, L, Liu D. W., Wang. J. M., et al. Correlation of crude cellulose content with moisture absorption and sensory quality of tobacco leaves. Southwest Journal of Agriculture Sciences, 2011, 24(2): 509-512.

[17] Elliot, J. M, Vickery, L. S. The effect of chlorine on the hygroscopicity of flue-cured tobacco. Canadian Journal of Plant Scinece, 1961, 41(1): 195-198.

[18] Wang, N. R., Li, Z. H., Fan, D. S., et al. Study on aging characteristics of roasted tobacco in Hechi, Guangxi. Journal of Anhui Agri Sci, 2009, 37(17): 7969-7971.

[19] Hu, Y. Z., Yang, S. Y., Li. Y. Q., et al. Changes in physicochemical indexes of B2F and C3F in Henan re-baked tobacco during aging. Tobacco Science & Technology, 2004(5): 11-15.

[20] Wang, L., Hu, Y. Q., Li, X. L., et al. Isotope tracing method to study the moisture transfer in tobacco during processing. Journal of Instrumental Analysis, 2008, 27(8): 812-815.

[21] Li, Y. Q., Hu, Y. Z., Zong, Y. L., et al. Changes of volatile and semi-volatile fatty acids and pH during aging of roasted tobacco. Flavour Fragrance Cosmetics, 2004(3), 21-24.

[22] Zou, Y., Yang, S. H., Xiong, W., et al. Study on the change of organic acid content during aging of roasted tobacco in Dali region. Yunnan Chemical Technology, 2007, 34(5): 41-45.

[23] Zhao, M. Q., Chen, H. H., Chen, Q. H., et al. Dynamic changes of polyphenols in roasted tobacco under different aging conditions and their correlation with chemical composition. Acta Tabacaria Sinica, 2007, 13(4): 16-18.

[24] Zhou, Y. F., Luo, J., Lin, Z. P., et al. Influence of the drying process on the phenolic content of

cigarette . Shandong Agricultural Sciences, 2016, 48(3): 36-38.

[25] Zhang, R., Yi, A. E., Xiang, N. J., et al. Research progress on analytical methods for tobacco wetting agents. Yunnan Chemical Technology, 2014, 41(3): 48-52.

[26] Zeng, S. T., Liu, Y., Liu, S., et al. Study on the factors influencing the moistening performance of tobacco leaves. Tobacco Science & Technology, 2011(8): 62-67.

[27] Ma, X. J., Ning, M., Xu, Y. B., et al. Research progress on the development and application of new natural tobacco wetting agents. Anhui Agricultural Science, 2015, 43(19): 260-263.

[28] Ye, C. F., Shao, P., Sun, P. L. Research progress of natural plants for tobacco aroma and moistening technology. Agricultural products processing, 2012(3): 33-38.

[29] Bai, J. F., Wei, K., Tang, Z. M., et al. Exploration of the moistening retention effect of Luo Han Guo additive and its mechanism of action. Enterprise Science and Technology and Development, 2019, 10:52-54.

[30] Huang, F. F., Jiang, J., Li, X. Q., et al. Ultrasonic extraction technology of Halophyllum multiflorum polysaccharide and its cigarette moistening properties. Tobacco Science and Technology, 2014(2): 44-48.

[31] Lei, S., Liu, X. M., Li, Y. D., et al. Effects of different plant polysaccharides on moisture absorption and moist retention of tobacco filaments and their action mechanism. Food and Machinery, 2019, 8: 49-54.

[32] Lin, C., Cui, H. P., Wang, X. J. Regulating water binding capacity and improving porous carbohydrate matrix's humectant and moisture proof functions by mixture of sucrose ester and Polygonatum sibiricum polysaccharide. International Journal of Biological Macromolecules, 2020(147): 667-674.

[33] Tan, H. X. Study on the effect of gum Arabic on the moistening properties of tobacco. Light Industry Science and Technology, 2014(6): 149-150.

[34] Lu, C. T., Hou, P., Sun, Z. T., et al. Carboxymethylation modification of Ganoderma lucidum polysaccharides and their wettability. Journal of Zhengzhou Institute of Light Industry, 2 015, 30(5/6): 49-53.

[35] Yan, H., Guo, G. N., Cheng, Y., et al. Study on the water retention performance of konjac glucomannan-based absorbent. Food Industry Science and Technology, 2010(03): 142-144.

[36] Liang, M., Zhang, G., Liu, C. M., et al. Effect of konjac glucomannan wetting agents on the moisture absorption characteristics of tobacco filaments. Food and Machinery, 2019, 7(35):204-208.

[37] Cheng, Y., Yan, H., Cai, B., et al. Study on the application of konjac glucomannan derivatives in tobacco moistening. Journal of Anhui Agricultural University, 2011, 38(1): 146-150.

[38] Lou, J. Y., Sha, Y. F., Yang, B., et al. Preparation of emulsified corn oil and its moistening properties . Tobacco Science and Technology, 2013(12): 36-40.

[39] Guo, J. C., Wu, D., Cheng, X. L., et al. Study on the effect of moistening agents on the moisture absorption properties of tobacco. Chinese Journal of Tobacco, 2013, 19(4): 22-27.

[40] Wang, T., Zhang, J. Z., Hu, L. Z., et al. Comparative study on the moisturizing performance and moisturizing effect of two moisturizing agents. Agricultural Basic Science, 2010(14): 16-17.

[41] Chen, Z. F., Lu, C. T., Sun, Z. T., et al. Synthesis and application of two polyhydroxylated rinse-preserving compounds. Chinese Journal of Tobacco, 2014, 20(3): 36-41.

[42] Guo, W., Tao, H., Yu, L. M., et al. Optimization of grapefruit peel polysaccharide extraction process and study of moistening properties. Agricultural Machinery, 2013(35): 56-59.

[43] Liu, Y., Liu, S., Hu, J., et al. Extraction of cactus polysaccharide and its application in cigarette. Tobacco Science and Technology, 2010(10): 8-11.

[44] Chi, J. G. Study on the moistening performance and application of natural tobacco moistening agents. Anhui Agricultural Science, 2013, 41(10): 4599-4601.

[45] Guo, G. N., Yan, H., Cai, B., et al. Study on the wetting retention performance of KSAP-T and its application, Anhui Agricultural Science, 2010, 38(12): 6569-6572.

[46] Yang, L. Liu, Y. Y., He, X. F., et al. Study on the

wetting performance of RSN-E, a new natural tobacco wetting agent. Food Industry, 2015, 36(1): 199-202.

[47] Jiao, K. X., Piao, Y. G., Li, H. L., et al. Extraction of loofah polysaccharides and its wettability study. Agricultural Products Processing, 2018, 4: 30-35.

[48] Ma, D., Ma, L., Wang, J. T., et al. Extraction of taro polysaccharide and its moisturizing effect on tobacco filaments. Agricultural Products Processing, 2019, 7: 55-58.

[49] Cui, B. H., Wang, X. J., Zhao, S. X., et al. Development of moisturizing agent SLT and its application in cigarette . Chinese Journal of Tobacco, 2011, 17(1): 38-41.

[50] Zhang, L., Zhang, X. H., Xu, L. X., et al. Influence of moistening agents on the moistening performance of cigarettes. Journal of Zhengzhou Institute of Light Industry, 2012, 27(5): 38-40.

[51] Yang, J., Huang, F. F., Ye, C. F., et al. Extraction process optimization of copper algae polysaccharides and their moistening properties. Tobacco Science and Technology, 2013(4): 37-41.

[52] Jia, Y. Z., Wang, Y. P., Qin, Y. Q., et al. Current status and development trend of tobacco wetting agent research. Light Industry Science and Technology, 2018, 1: 26-28.

[53] Yi, J. M., Wen, J., Yang, Q. Comparison of the performance of several wetting agents. Tobacco Science and Technology, 2006(4): 9-12.

[54] Liu, J. Y., Zhao, Y., Fu, M. S., et al. Effects of several wetting agents on the chemical composition of cigarette smoke. Physical and chemical examination, 2013, 49(6): 738-742.

[55] Lai, H. L., He, R., Wen, P., et al. Wax ester-based tobacco wetting agents and their preparation methods: CN101658323. 2009.

[56] Liu, S. H., Mao, D. B., Bai, J. F., et al. A new type of tobacco wetting agent and its application method: CN, 103859575. 2014.

[57] Xu, R. F., Deng, G. B., Li, Z. H., et al. Development and application of natural mushroom mushroom tobacco flavoring materials. 2006, 23(11): 1089-1093.

[58] Liu, Z. H., Cui, L., Miu, M. M., et al. Effects of potassium sodium citrate salt mixer on mainstream cigarette smoke. Tobacco Science and Technology, 2008(12): 10-13.

[59] Zhou, B., Zhang, T. D., Li, G., et al. Application of lactic acid and lactate in cigarette moistening. Chinese Journal of Tobacco, 2011, 17(6): 8-12.

[60] Bai, L. Preparation and study of new tobacco combustion aids with moistening properties. Zhengzhou University, 2010.

[61] Yin, C. Study of potassium lactate to improve the moistening performance and smoke quality of cigarette. Jiangnan University, 2014.

[62] Ai, Q. Research on the effect of bionic protectants on the moistening and moisture-proofing of cigarette . Shanghai Tobacco Industry, 1994(2): 14-16.

[63] Chen, J. J., Li, Q., An, Y., et al. Performance of two-way wetting agents and their application in cigarettes. Chinese Journal of Tobacco, 2008, 14(z1): 21-24.

[64] Xu, F., Ye, H. Y., Zhang, J. Z., et al. Organic-inorganic hybrids of mesoporous titanium phosphonate material for reducing hazardous components in cigarette smoke. Acta Tabacaria Sinica, 2014, 20(6): 6-11.

[65] Xu, F., Ye, H. Y., Zhang, J. Z., et al. Factors influencing casing effects of cut strips. Tobacco Science & Technology, 2014, 10: 5-8.

[66] Wu, R. X., Xiao, X. M., Xing, L. X., et al. Simultaneous Determination of Sixteen Aroma Components in Flavors and Tobacco by Gas Chromatography-Tandem Mass Spectrometry. Flavour Fragrance Cosmetics, 2020, 2(1): 9-15.

[67] Wu, R. X., Zhang, C. T., Li, D. K., et al. Accelerated solvent extraction - Gas Chromatography - Tandem mass spectrometry determination in tobacco 5 phenethyl carboxylate in tobacco and Evaluation of the uniformity of flavouring in tobacco. PTCA(Part B: CHEM. ANAL.), 2020, 56(1): 7-13.