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Diploma Thesis

Storage aspects of the Flue-Cured Virginia tobacco ageing in India

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CONTENT

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II. DECLARATION

I hereby declare that I have worked on this Diploma Thesis on my own. All information sources are quoted in References.

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III. ABSTRACT

Tobacco is the most extensively studied plant material in the history, because of its complex chemical composition. During its production, tobacco leaf goes through many different operations from curing (drying) to ageing. Among all of them, storage and ageing are very important operations, since proper stored tobacco develops its full flavour, becomes more aromatic, and is ready to be sent to a customer for cigarette production. This Diploma Thesis focuses on the post-harvest operations, processing and storage technologies of NLS (Northern Light Soils, India) FCV (Flue-Cured Virginia) tobacco. Four samples of aged NLS FCV tobacco were analyzed: two different liners (Polyliner and Kraft paper) were used for packing tobacco from 2011 and 2012 years. Quality evaluation of tobacco samples was done according to the results of analysis report of chemical components (total alkaloids, reducing sugars, oven volatiles on dry basis), volatile profile, and colour changing during the ageing process. Organoleptic analyses were performed as a final assessment of tobacco flavour and quality.

Key words: tobacco, post-harvest operations, drying, storage, packing, quality evaluation.

ABSTRAKT

Tabák se historicky vzhledem k jeho chemickému složení řadí mezi nejsledovanější rostlinné materiály. Během posklizňového zpracování prochází tabákové listy mnoha operacemi od sušení až po jeho zrání. Proto jsou skladování a zrání velmi důležitými operacemi, neboť jen správně skladovaný tabák rozvíjí plnou chuť, stává se více aromatickým a je připraven k výrobě cigaret pro konzumenty.

Tato diplomová práce se zabývá posklizňovým zpracováním tabáku, zpracováním a technologií skladování tabáku NSL (Northern Light Soils – Severní lehké půdy, Indie), FCV (Flue-Cured Virginia – viržinský tabák sušený proudem vzduchu).

Byla provedena analýza 4 vzorků zralého tabáku NLS FCV. Pro balení tabáku ze sklizní 2011 a 2012 byly použity 2 různé druhy obalu (Polyliner – plastový obal a Kraft paper liner – druh kartonového obalu). Hodnocení kvality tabáku bylo provedeno na základě výsledků analýz chemického složení vzorků tabáku (celkové alkaloidy, redukující cukry, těkavé látky po zahřátí, a barevné změny během procesu zrání). Organoleptické vlastnosti byly finálním hodnocením chuti, aroma a kvality tabáku.

Klíčová slova: tabák, posklizňové operace, sušení, skladování, balení, hodnocení kvality.

1. INTRODUCTION

Tobacco is one of the most economically significant agricultural crops in the world. Found by Christopher Columbus and his crew in 1492, tobacco became very popular in the whole world during the next century. However, it is believed that the history of tobacco begins much earlier, 2.5 million years ago.

Nowadays, tobacco is grown in many countries of Asia, America, Europe, and Africa. About 4.2 million hectares of soil were used for tobacco growing worldwide in 2000, yielding over 7.5 million tons of tobacco leaves. The biggest producers and consumers are China, India, Brazil, USA and European Union. India and Brazil are two biggest producers of Flue-Cured Virginia tobacco, which is the main component in cigarette blends.

Tobacco is a plant belonging to the genus *Nicotiana*, family *Solanaceae*. It is the most widely consumed non-food plant in the world. The genus *Nicotiana* has more than 60 species, of which just two are commercially cultivated for the production of tobacco: *N. tabacum* and *N. rustica*. *N. tabacum* is more preferable for tobacco production because of its smooth tasting comparing to *N. rustica*. *N. tabacum* is widely cultivated in most countries of the world. Its leaves are used for smoking, snuffing, chewing, or dipping tobacco. The most used types of tobacco are Flue-Cured Virginia (FCV), Burley, and Oriental tobacco. FCV tobacco is known for its sweet and aromatic taste and mainly used for cigarette production. The main exporters of FCV tobacco are Brazil and India.

After being harvested, tobacco leaf goes through many operations to become a final product. It should be cured (dried) and graded according a complex of physical characteristics. Cured leaf is processed in the green leaf threshing plant (GLT) to separate lamina from stem (midrib). After packing, tobacco products are stored and aged in warehouses during a period from 6 months to a couple of years. During every operation, quality of the product is controlled: according to its either physical or chemical characteristics.

Tobacco storage and ageing are the last and very important operations before sending tobacco to a customer. Proper stored tobacco develops its full flavour, becomes more aromatic and usually darkens in colour. It is necessary to provide quality control of the packed tobacco to avoid any mould or pest damage, since it may lead to the loss of the product. Tobacco may be packed with two different types of liners according to customer's request: Polyliner and Kraft paper liner. Tobacco stored either with Polyliner or with Kraft paper differs in colour, aroma and taste, and physical characteristics. In this Diploma Thesis, post-harvest and processing operations, tobacco storage and ageing were studied on example of the NLS (Northern Light Soils) FCV (Flue-Cured Virginia) tobacco.

2. LITERATURE REVIEW

2.1 Tobacco history

As Huron Indian myth says, "In ancient times, when the land was barren and the people were starving, the Great Spirit sent forth a woman to save humanity. As she traveled over the world, everywhere her right hand touched the soil, there grew potatoes. And everywhere her left hand touched the soil, there grew corn. And when the world was rich and fertile, she sat down and rested. When she arose, there grew tobacco…" [12]

History of tobacco growing dates back in year 6000 B.C. It is considered, that the first place of tobacco cultivation was the area around the Lake Titicaca. To shamans of certain South American Indian tribes, tobacco was the nourishment of the supernaturals. The first tobacco plantations for cigar production were organized in the Dominican Republic (1521), Cuba and the Philippines. [42]

However, in 2010, paleontologists from the Meyer-Honninger Paleontology Museum found that tobacco dates to the Pleistocene Era 2.5 million years ago. They discovered the small block of fossilized tobacco in the Maranon river basin in northeastern Peru. [39]

According to Gene Borio, generally, tobacco history can be divided in the following parts:

a) Discovery (15th century);

b) Spreading of tobacco seeds (16th century);

c) the Age of pipes (17th century);

d) the Age of snuff tobacco (18th century);

e) the Age of cigars (19th century);

f) the rise of the manufactured cigarettes (20th century).

Christopher Columbus, the man who discovered America, mentioned tobacco in his journal on October 15th, 1492. "We found a man in a canoe going from Santa Maria to Fernandia. He had with him some dried leaves which are in high value among them, for a quantity of it was brought to me at San Salvador." [40]

In 1531, the first tobacco cultivation by European settlers began in Santo Domingo. In 1558, tobacco plant was brought to Europe, but attempts to cultivate it failed. In early 1600's, tobacco had been introduced into Asian countries. [44]

In 1612, American farmers began to grow tobacco commercially. Since that moment, thousands of tobacco shops were opened. Tobacco became very popular in Europe because of its supposed healing properties. Europeans believed that tobacco could cure almost anything, from bad breath to cancer. During the 1600's, tobacco began to be used as money. In 1776, during the American Civil War, George Washington said: "I say, if you can't send money, send tobacco." [44] Tobacco helped finance the revolution by serving as collateral for loans the Americans borrowed from France. [26]

In 1881, cigarette machine was invented. Since that moment, cigarettes began to replace traditional cigars and pipes. Many well-known cigarette companies were opened since then: 1885 – British "Philip Morris" (incorporated in New York in 1902), 1901 – "UK Imperial Tobacco", 1902 – "British American Tobacco". In 1913, R.J. Reynolds Tobacco Company produced the first packed cigarettes. Along with the popularity of cigarettes, however, there was a small but growing anti-tobacco campaign, with some states proposing a total ban on tobacco. [26]

2.2 Health impacts of tobacco

Tobacco leaf is valuable for its nicotine content. Nicotine ($C_{10}H_{14}N_2$) is an alkaloid, which is produced in the roots and transported to the leaves of the plant to prevent them from eating by herbivore animals. [27]

After tobacco was brought to Europe in 16th century, it was promoted as a medicine. In 1571, a Spanish doctor Nicolas Monardes wrote a book about the history of medicinal plants of the new world, and he claimed that tobacco could cure 36 health problems. In 1826, after discovering the pure form of nicotine, it was considered as a dangerous poison. After this, nicotine had been used as an insecticide as well.

The first major report on “Tobacco and Health” came out in 1964. After World War II, when cigarette smoking increased significantly, a lot of evidence were surfacing that smoking can be a reason of lung cancer, but tobacco companies refused this information and began to produce “safer” cigarettes with lower tar and filters. The “Tobacco and Health” report assisted in allowing the government to regulate the advertisement and sales of cigarettes. Since that moment, year by year, cigarette ads began to disappear from television and were completely taken off in USA. Health warnings started to appear on cigarette packs. It was a big hit for tobacco industry. Not to lose money, some of major tobacco companies began their non-tobacco activities: Philip Morris started Miller Brewing Company; R.J. Reynolds came into aluminum production. Also, R.J. Reynolds Tobacco Company dropped the “Tobacco Company” in its name and became R.J. Reynolds Industries, as well as American Tobacco Company became American Brands, Inc. [26]

As it is reported, smoking can be the reason of lung cancer, arteriosclerosis, coronary heart disease, strokes, emphysema, etc. Nowadays, smoking is banned in many places to avoid health risks of passive smoking (second-hand smoking). No smoking is allowed in public places such as restaurants, workplaces, or in public transport.

Cigarette smoke contains hundreds of chemical substances; the most damaging of these are nicotine, tar, and carbon monoxide. As it was said before, nicotine is an alkaloid, and just like caffeine, it is a stimulant. It provokes nerve cells in the brain and heightens awareness. [29] After inhaling, smoker feels relaxation due to decreased pressure in the chest and veins, increased blood and oxygen flow to the heart. Nicotine-rich blood passes from the lungs to the brain and affects nicotine receptors, which results in physical uplift. But, after stimulating nervous system, smokers gets tense feeling of increased heart rate and respiration due to release of adrenalin. [32]

Nicotine is highly addictive both in psychological and physiological ways, however, it is possible to quit smoking.

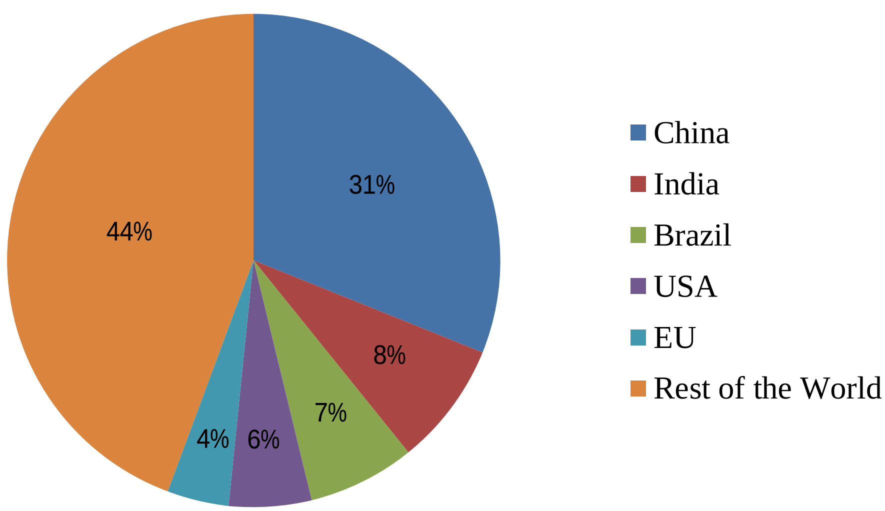
2.3 Tobacco economy

2.3.1 Tobacco production

Nowadays, tobacco is grown in many countries of Asia, America, Europe, and Africa. About 4.2 million hectares of soil were used for tobacco growing worldwide in 2000, yielding over 7.5 million tons of tobacco leaves. The biggest producers and consumers are China, India, Brazil, USA and European Union. [13]

According to Food and Agricultural Organization of the United Nations, production shares for the world in 2000, shown in Fig. 1, were 31.3% (2.3 million tons) for China, 8.1% (600 thousand tons) for India, 7% (520 thousand tons) for Brazil, 5.4% (400 thousand tons) for USA, 4.1% (300 thousand tons) for European Union.

Fig. 1 Tobacco production shares in the World, 2000



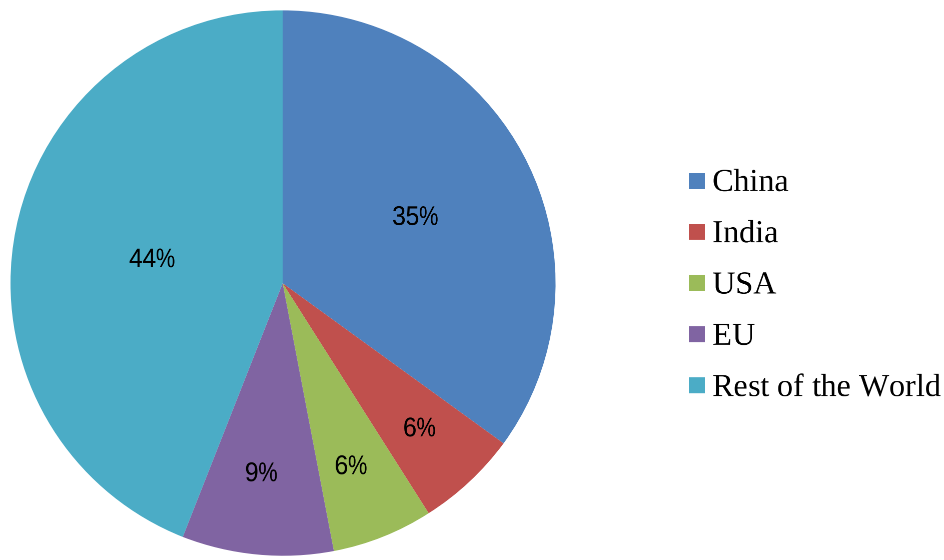
2.3.2 Tobacco consumption

World tobacco consumption increased by over 75% during the second half of 20th century, from 4.2 million tons in 1970 to reach 7.4 million tons of tobacco leaf equivalent in dry weight in 2000. Over 70% (about 5.3 million tons) of the world total is consumed in the developing countries. Consumption in developed countries declined from 2.3 million tons in 1970 to 2.1

million tons in 2000, while in the developing countries it increased from 2.1 million tons in 1970 to 5.3 million tons in 2000. Much of the increase in developing country consumption is accounted for by China where consumption increased from a little under 0.7 million tons in 1970 to 2.6 million tons in 2000. [13]

According to Food and Agricultural Organization of the United Nations, consumption shares for the world in 2000, shown in Fig. 2, were 35% (2.59 million tons) for China, 6% (440 thousand tons) both for USA and India, 9% (670 thousand tons) for European Union.

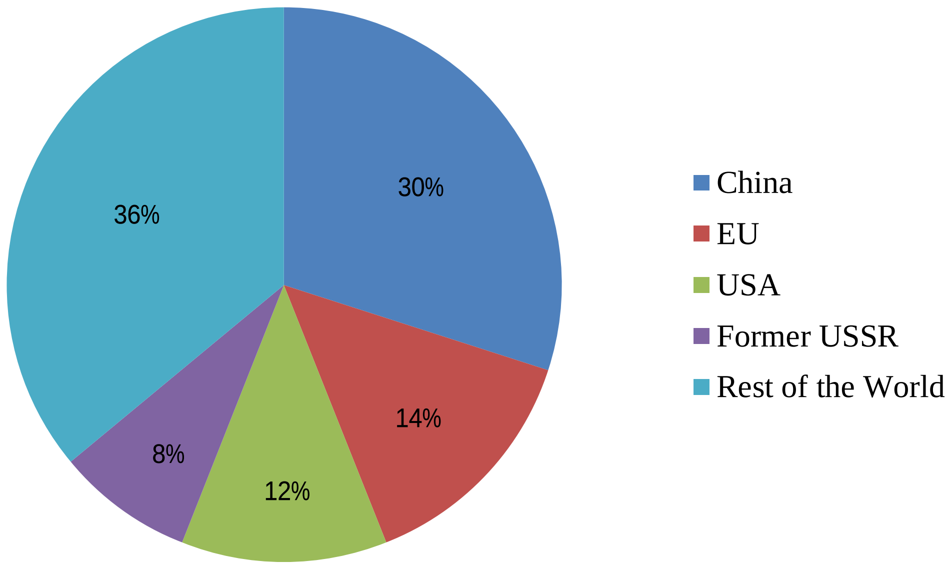
Fig. 2 Tobacco consumption shares in the World, 2000



2.3.3 Cigarette production

World cigarette production increased from 3 million tons in 1970 to 5.6 million tons in 2000 due to increasing production in developing countries. In developed countries, cigarette production shows only a small increase from 2 million tons in 1971 to 2.5 million tons in 1991, remaining stable around this level since. [13] See Fig. 3.

Fig. 3 Production shares of cigarettes



The largest cigarette producing companies are:

a) China National Tobacco Corporation (Government-owned corporation, monopoly);

b) Philip Morris International, Inc. (Revenue: US$ 76.34 billion (2011));

c) Imperial Tobacco Group plc (Revenue: £28.57 billion (2012));

d) Altria Group, Inc. (Revenue: US$ 23.8 billion (2011));

e) British American Tobacco plc (Revenue: £15.2 billion (2012));

f) Japan Tobacco, Inc. (Revenue: ¥2.033 trillion (2012)).

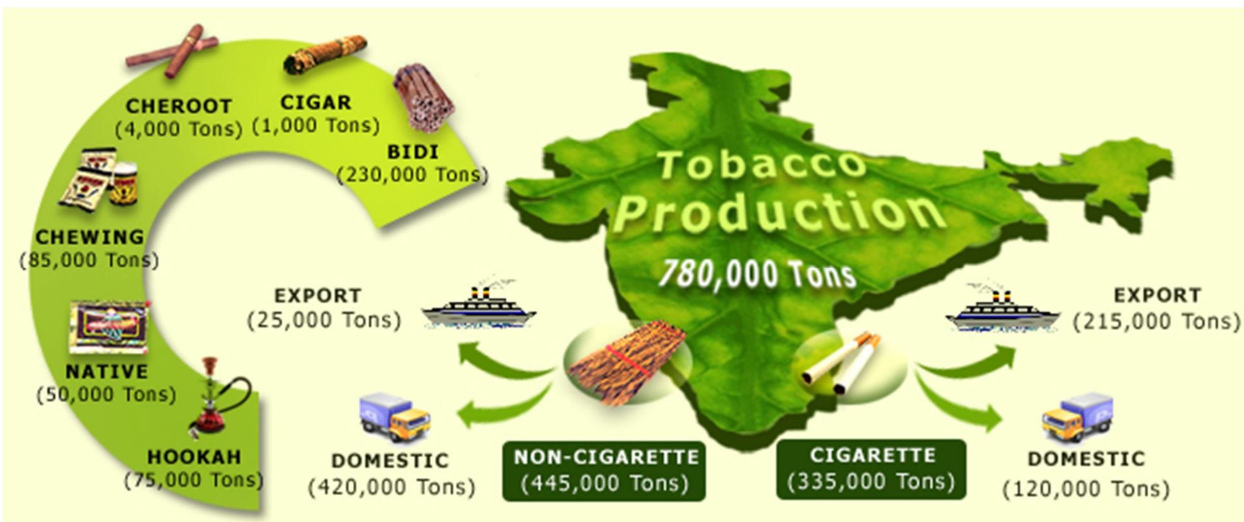
The demand for tobacco continues to increase, but, as it was said before, cigarette consumption in many developed countries, the USA in particular, has tended to decline over the past decade, but this downward trend seems to be leveling out. Further government regulations, such as restrictions on advertising, could have its negative effect on the demand for tobacco products. [9]

2.3.4 Indian tobacco industry

Indian tobacco is known for its low pesticide residues and heavy metals, low TSNA (tobacco specific nitrosamines) levels, and the availability of wide range of tobaccos at competitive prices.

In the tobacco world, India has a very impressive and progressive profile. From 2000 to 2010-2011, production of tobacco increased from 600 million kg to more than 700 million kg. Of this, FCV tobacco is the main exportable variety of tobacco (80%); it is grown in the states of Andhra Pradesh and Karnataka. NLS FCV is known as a premium tobacco with good ageing properties; Mysore FCV is the largest exported crop of India; whereas, SLS and Traditional FCV tobaccos are used as neutral and coloury fillers. India produces 300 million kg and is the second largest exporter of FCV tobacco after Brazil. [33]

Fig. 4 Tobacco production in India

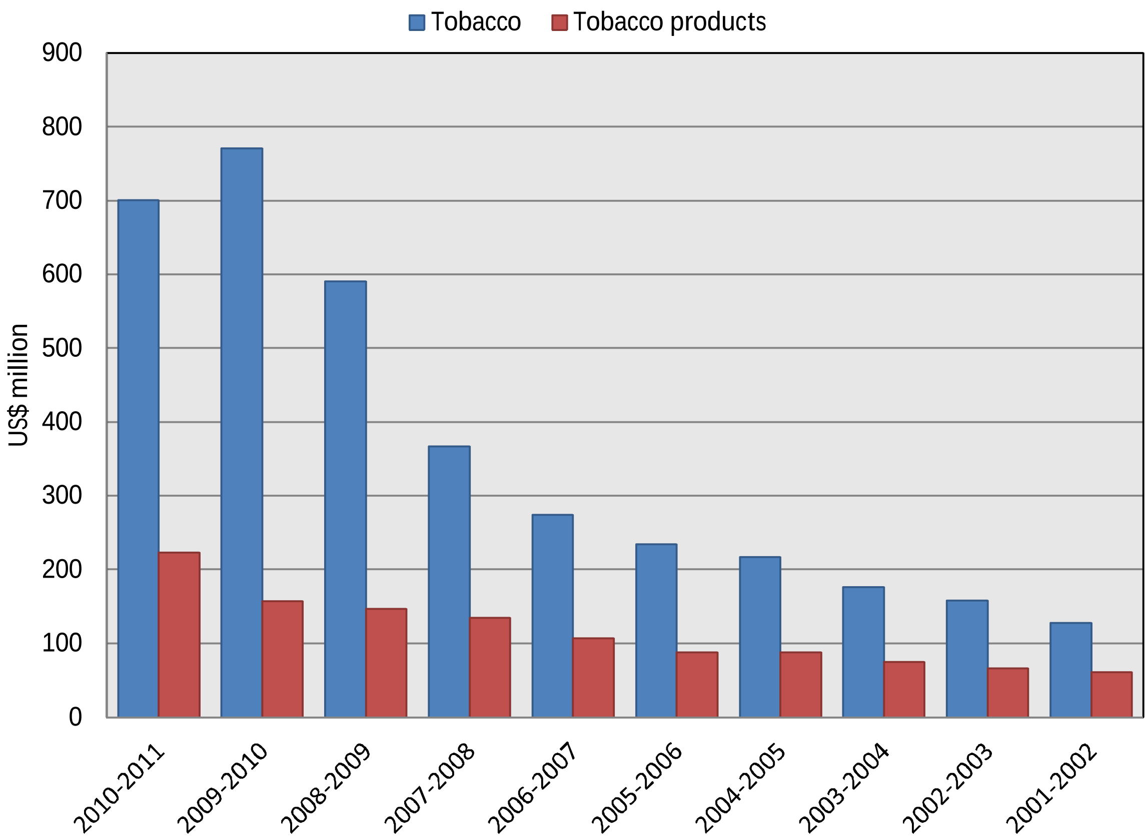


Source: ITC – ILTD

40% of tobacco products are used for cigarette production, while 60% are used for non-cigarette production: bidi, cigar, chewing, hookah, and other tobacco production. Overall, 70% of tobacco products are used for domestic production (Fig. 4).

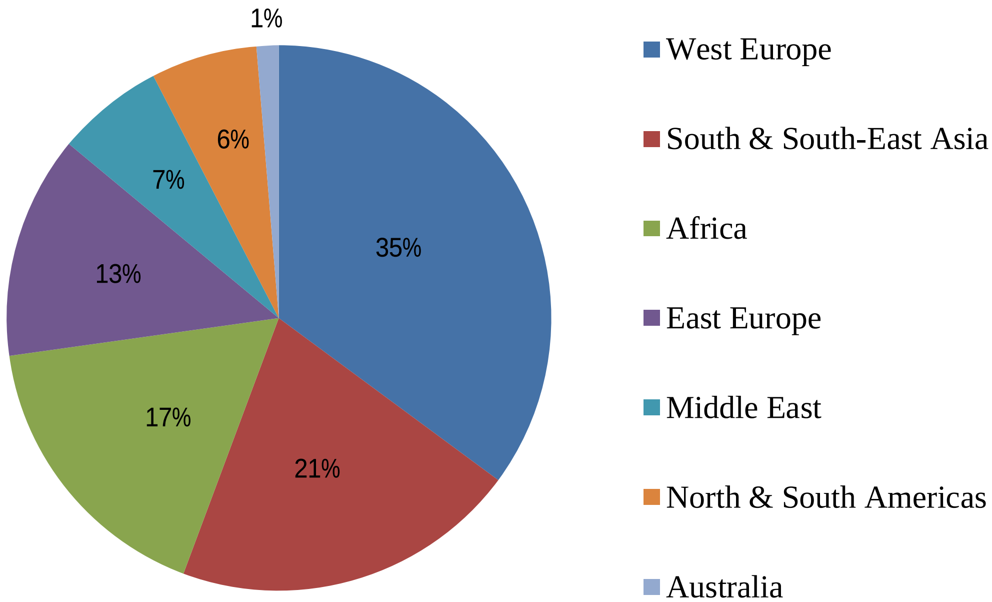
Tobacco makes a significant contribution to Indian economy by earning US$923.94 million of foreign exchange in 2010-2011. Exports of tobacco and tobacco products were increasing constantly during the period from 2001-2002 to 2010-2011 (Tab. 5). During the decade, exports have grown by 489%. [33]

Fig. 5 Exports of Indian tobacco and tobacco products



India exports unmanufactured tobacco primarily to Europe, South and South-East Asia, and Africa. Belgium is the largest market for Indian FCV tobacco, followed by Korea and Russia. Overall, in 2010-2011, India exported 74,651 tons of unmanufactured tobacco to West Europe, which is 35% of overall exports. See Fig. 6 for destinations and shares of exports of Indian unmanufactured tobacco. [33]

Fig. 6 Regions of exports of unmanufactured tobacco in 2010-2011



2.4 Tobacco plant botany

Tobacco is a plant belonging to the genus *Nicotiana*, family *Solanaceae*. It is the most widely consumed non-food plant in the world. The genus *Nicotiana* has more than 60 species, of which just two are commercially cultivated for the production of tobacco: *N. tabacum* and *N. rustica*. According to Sharma, though the tobacco plant is tropical in origin, its production at present is concentrated mostly outside the tropics, except in India. [30] The most appropriate terminology is the classification into types according curing method and usage, followed by reference to cultivars or varieties within each type. [34]

Both *N. rustica* and *N. tabacum* are annuals with a singular flower-bearing stem and tens of large, ovate leaves. A single ripe fruit, or capsule, from either species may contain 2-4 thousands of seeds. One table spoon can sow 100 $yards^2$ (approximately 84 m^2). *Nicotiana sp.* seeds are minute, ranging between 0.4-1.3 mm in diameter. The mass of 1,000 of tobacco seeds is 0.06-0.08 of gram. [11, 14, 37, 43]

2.4.1 *Nicotiana rustica*

Mature *Nicotiana rustica* (Fig. 7) typically ranges between 2 and 4 feet tall and has greenish-yellow flowers. *N. rustica* was grown and exported by colonists in the East, until it was replaced by the smoother tasting *N. tabacum* in the mid 1600's. [5, 16]

Fig. 7 *Nicotiana rustica* plant

Source: Köhler's Medizinal-Pflanzen

Dried leaves of *N. rustica* plants can contain up to 9% nicotine, whereas *N. tabacum* nicotine levels tend to range between 1% and 4%. The high concentration of nicotine in its leaves makes it useful for creating organic pesticides. In India, *N. rustica* is used as chewing and hookah tobacco, for tobacco sheet making and pipe mixtures. In Russia, it is known as “makhorka” and was smoked by lower classes before normal tobacco became widely available in the second part of the 20th century. [5, 34]

2.4.2 *Nicotiana tabacum*

Nicotiana tabacum cannot be found in wild form. *N. tabacum* plants (Fig. 8) typically range from 4 to 8 feet, depending on the variety and have pink flowers. [5, 16]

Fig. 8 *Nicotiana tabacum* plant

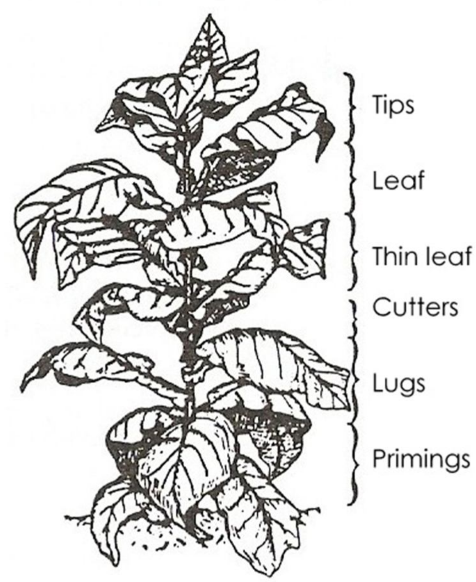
Source: Köhler's Medizinal-Pflanzen

Nowadays, *N. tabacum* is widely cultivated in most countries of the world. Its leaves are used for smoking, snuffing, chewing, or dipping tobacco. The most used types of tobacco are Flue-Cured Virginia (FCV), Burley, and Oriental tobacco.

Virginia tobacco is named after the State of Virginia in USA, where this tobacco was first grown. Today Virginia tobacco is grown in many other countries. Flue-Cured Virginia tobacco is known for its sweet and aromatic taste because it has low nicotine content (1.5-4%; 1.5-3.5% for NLS FCV) and high sugar levels (7-27%; 7-18% for NLS FCV). FCV tobaccos vary in strength from very mild to medium, depending on where the leaf is positioned on the plant, and on the local growing conditions. Virginia tobacco leaves are 20-50 cm long and light golden to dark mahogany in colour. This tobacco blends well any other tobacco. [18, 21, 34, 36]

Leaves of the FCV tobacco are divided by farmers in the following groups:

Fig. 9 FCV leaf position



First grade leaves (good lugs and best leaf) of the FCV tobacco are only 10% of all plant's leaves. Second grade leaves (sand lug and second leaf) are 36%, third grade leaves (trash lugs and tips) are 37%, and fourth grade leaves (scrap trash, primings, and green tips) are about 17%. [7, 18, 19]

Unlike FCV, Burley tobacco is a high nicotine type (2-4%) of tobacco and has low sugar levels (1.5-3%), which originated with a plant found in 1864 in Brown Country, Ohio. It was an aurea variety and probably a mutation. The present Burley varieties have been developed by crossing this White Burley with other varieties. The taste of Burley tobacco is relatively strong, full and dry. Burley tobacco leaves are 20-50 cm long, the colour varying from light to very dark brown. Burley tobacco is used as blend in cigarettes, for pipe mixtures, chewing plugs and hookah tobacco paste. [30, 34, 36]

Oriental tobacco originates from the eastern Mediterranean. Today, the best quality leaves are grown in Turkey and Greece. The leaves of Oriental tobacco vary in size and shape, from small heart shaped leaves of 2 cm length to larger arrow shaped leaves of 15 cm length. The colour of Oriental tobacco leaves vary from light golden to dark orange; however, certain types have leaves of a dark greenish hue. Oriental tobacco is typically very mild in strength with a slightly sweet and strongly aromatic taste. The strong aroma is developed because the tobacco is grown in very dry conditions; the tobacco plant forms a layer of wax on the leaves to prevent them drying out. This layer of wax contains natural aromatic oils. [34, 36]

2.4.3 Planting

In India, the species *N. tabacum* are grown in almost all of the states, whereas the cultivation of *N. rustica* is confined to the northern and north-eastern states, where the temperatures are considerably lower during the growing season. Tobacco is very sensitive to the physical and chemical properties of the soil. The best soils are those which are open, well drained and properly aerated. In India, FCV tobaccos are grown on sandy or sandy loam soils. The area where tobacco was grown is a very important characteristic of tobacco quality; it should be put in the name of tobacco: NLS (Northern Light Soil), SLS (Southern Light Soils), BCS (Black Cotton Soils), etc. Tobacco plant is highly susceptible to injury from flooding or inundation of the soil. The desirable soil pH is from 5.0 to 6.0, but in many parts of India, cultivation is successful where the pH is 8 or more. [18, 19, 30]

Since tobacco seeds are so small, they are usually mixed with other materials such as sand, fertilizer, lime or water during seeding operation. [9] Before planting, young tobacco plants should go through nursery period, which results in uniform and robust growth. It includes seedling raising in polypots of vermicompost and soil, resetting seedlings in tray, seedling replanting in fresh beds. It is essential that good quality seedlings are used as transplants. They should be about 15 cm in height and free from any pests or diseases. Under favorable conditions, new roots are formed 4 days after transplanting, and small increases of the above ground parts occur during subsequent 7 to 10 days. [18, 19]

Dates of planting of tobacco crop depend on its type and area conditions. In India, FCV tobacco is planted in early May in Karnataka (during summer season before monsoons), whereas FCV tobaccos in NLS (Northern Light Soils) and SLS (Southern Light Soils) areas are planted between October and mid-November. Spacing between crops is 100 x 60 cm (sometimes 105 x 60 cm), which means there will be approximately 16,660 plants per hectare. Fertilization by sodium, phosphorus, and potassium (120:60:140 kg NPK for NLS) is done in three splits.

Irrigation for FCV grown in NLS regions should be done 12-14 times, whereas tobacco grown in Karnataka does not require irrigation because of the monsoon period. [18]

2.4.4 Growing

Tobacco is a very light-requiring crop. The lack of sunlight may result in deceleration of carbohydrates accumulation, changing of leaf structure, and loss of aromatic properties. [43]

Overall, the length of vegetation period depends on the average day temperature (Tab. 1).

Tab. 1 Dependence between average temperature and length of vegetation period

Average temperature, °C	Vegetation period, days
18	175
20	130
26-27	100

Source: www.ecosystema.ru

The length of tobacco growing period in the field varies from 35 to 60 days.

Topping is one of the most important procedures during tobacco growing period. Topping is a process of removing of the flower-head alone or along with some of the top leaves of the plant. After topping, the axillary buds grow and their removal is known as suckering. Topping and suckering tend to increase size, thickness, body, and nicotine content of the leaves (Fig. 10). Topping has a much greater effect on the chemical and physical properties of younger than older leaves. The upper leaves of topped plants are much larger, thicker and heavier-bodied than those from untopped plants. [3, 9, 19, 30]

Fig. 10 Tobacco plant after and without topping

The level of topping varies from type to type. In case of FCV tobacco, topping should be done at 20-24 leaves, and for *N. rustica* topping should be done at 6-8 leaves. [30]

Removing suckers by hand is very laborious and time-consuming job. Hence, a number of experiments for the suppression of suckers by the application of suckercides were conducted. Suckercide is a chemical applied to tobacco plants to prevent suckers. Depending on their mode of action, tobacco suckercides are divided in three categories: fatty alcohol contacts, contact alcohol systematics, or systematics. [19, 34]

2.4.5 Harvesting

The signs of maturity and the methods of harvesting vary among different types of tobacco. The FCV tobacco is harvested during December-March in NLS area and during July-September in Karnataka. The leaves are considered ready for harvesting when the green colour changes to yellowish green or light yellow and brownish spots appear. Harvesting is done manually and starts from the bottom, each time 2-3 leaves are harvested. As a general rule, the leaves are harvested from the bottom primings slightly on the green side, the middle leaves when they are ripe and the top leaves when they are fully ripe. A well-matured leaf will snap crisply with a characteristic sound. The leaves are to be carried carefully without pressing to one end of the field and placed carefully in a wide basket with tips upward. [19, 30]

It is easy to count how many tobacco leaves a farmer can harvest from 1 hectare of the plantation:

- each plant has 20-24 leaves, 22 leaves in average;
- as it was said before, there are approximately 16,660 plants per hectare;
- so, a farmer can harvest around 366,500 leaves from 1 hectare.

After being harvested and loaded in a truck, leaves are tied on bamboo sticks. There can be from 60 to 100 leaves on one stick, depending on their size. The leaves are distributed uniformly all over the length of the stick to avoid overcrowding. [19]

Since that moment leaves are ready for post-harvest operations.

2.4.6 Leaf components

Tobacco is the most extensively studied plant material in the history, since its complex chemical composition. Today, around 3,000 chemical compounds have been identified in a tobacco leaf. [9] The chemical and physical properties of the leaf depend on many factors, such as genetics, soil type, climate, weather and number of sunny days, stalk position, harvesting, curing and storage conditions. Yet, the quality of tobacco is judged mostly by empirical experience and subjective sensorial (organoleptic) evaluations. [10, 35]

Tobacco leaf is valuable for its alkaloids. Alkaloids in tobacco are extremely important characteristic of tobacco quality. Nicotine is the main alkaloid of tobacco leaf, accounting around 90-95% of the total alkaloids. Nornicotine, anatabine, and anabasine are the most abundant of the minor alkaloids (5-10%). Nornictoine content has a negative impact on tobacco quality. Leaf lamina contains the greatest concentration of alkaloids. During the time between topping and harvesting, the change on nicotine concentration in the leaves may be up to 400%.

Carbohydrates are present in tobacco in different forms: cellulose, starch, sugars, etc. The main sugars are glucose and fructose; however, small amounts of maltose and sucrose are also to be found. Their by-products of decomposition have beneficial effects on the quality of the smoke.

The “sugars” refer to naturally occurring reducing sugars as dextrose. FCV tobaccos are characterized by the presence of sugar in their leaves. The amount of nicotine vs. sugars is usually an inverse relationship. Tobaccos high in sugar are usually low in nicotine and tobaccos high in nicotine are low in natural sugars.

Tobacco proteins have a negative influence on tobacco quality, especially on taste, producing ammonia and nitrogenous components which make the smell unpleasant. However, some proteins are essentials for full taste. [34]

The volatile C_2-C_8 organic acids are known to be important aroma compounds in many fruits, as well as in tobacco. These acids are some of the most important contributors to smoke quality. The main organic acids of tobacco leaf are formic and acetic acids. [17] As well as organic acids, tobacco surface waxes are important components in aroma forming. Surfaces waxes are resinous components of the tobacco leaf cuticle. They contain terpenes and other substances which determine the taste or smell of the leaf and aroma of the smoke. Carotene ($C_{40}H_{56}$) is a yellow pigment occurring in dying tobacco leaves. When degraded, it produces well-flavoured tobacco. [34]

2.5 Tobacco post-harvest operations

2.5.1 Curing

Curing is the drying process for newly harvested tobacco leaves. Methods of curing depend on type of tobacco are shown in Tab. 2. [1, 11]

Tab. 2 Methods of tobacco leaf curing

Method of curing	Type of tobacco	Use
Air	Virginia	Pipe, chewing, cigarettes, snuff
	Burley	
	Amarelo	
	Cigar	Cigars
	Local	All uses
Sun	Oriental	Cigarettes, pipe
	Local	All uses
Fire	Virginia	Pipe, chewing, cigarettes
Flue	Virginia	Cigarettes, pipe
	Amarelo	

Air curing is performed in widely ventilated barns under natural atmospheric conditions with no or little application of artificial heat. Usually, it takes from 4 to 8 weeks, but sometimes it may vary between 3 and 12 weeks. Air-cured tobacco is low in sugar, which gives the tobacco smoke a light, sweet flavour, and high nicotine level. Light air-cured tobacco is very thin to medium in body, light tan shaded toward red to reddish brown in colour, and mild in flavour.

Sun curing is performed on racks in the sunshine. It takes over 4 weeks, depending on the weather. This method is used in Mediterranean countries to produce oriental tobacco. Sun-cured tobacco is low in sugar and nicotine and is used in cigarettes. It looks similar to air-cured tobacco.

Fire curing is performed in ventilated barns with open fires allowing the smoke to contact the tobacco leaves. Flue-cured tobacco is light to dark brown in colour, medium to heavy in body, and strong in flavour. Fire curing produces a tobacco low in sugar and high in nicotine.

Flue curing process apparently originated in 1839 in Caswell Country, North Carolina. Today, flue-cured tobacco is used primarily in cigarettes and it is the major component of the blended cigarette (Collins and Hawks, 1993). Flue curing is performed in 4 stages in specially constructed barns. The name comes from the metal flues used in the heating apparatus. Flue-cured tobacco is orange to reddish-orange in colour, thin to medium in body, and mild in flavour. It takes about Flue-curing process takes from 5 to 7 days. [11, 34]

Barns for flue-curing are 16 x 16 x 16 feet in size. Heat is produced by burning of wood in furnace placed in the back of the barn. Pipes of a flue system inside of the barn are slightly inclined to make hot air flowing inside of the pipes easier. The main pipe is placed on the ground in the middle; a net should be placed above it during a curing process to prevent fire (drying leaves might fall down, if not tied properly). Then the main pipe is split in two side pipes, which are placed along the side walls of the barn. At the back wall, right above the main pipe, side pipes are connected again, which allows hot air to flow to a chimney pipe. For ventilation during different stages of curing, there are 4 bottom (1 x 2 feet) and 1 top (2 x 3 feet) ventilators.

The whole barn should be loaded with freshly harvested leaves from single priming. The un-ripe leaves (green) are placed on the top tiers, the over-ripe leaves (yellowish-white) leaves on the bottom tier and well-matured leaves (greenish-yellow) in the bulk of the intermediate tiers. A 16 x 16 x 16 feet barn can be loaded with 600 sticks with spacing 4 (horizontally) x 3 (vertically) feet between them. Loading of the barn should be completed by late afternoon. All work is done by hand. [19]

As it was said before, there are 4 stages of flue-curing. See Tab. 3.

Tab. 3 Flue-curing stages

Stage	Duration, hours	Temperature, °C	Air humidity, %	Leaf moisture, %
Yellowing	48	30 - 40.5	90 → 55	80 → 60
Colour fix	12	40.5 - 52	55 → 28	60 → 45
Lamina drying	45	52 - 60	28 → 25	45 → 15
Stem drying	45	60 - 71	25 → 15	15 → 8

Source: ITC – ILTD

The early stage of flue-curing should permit continuing biological activity in the leaf permitting destruction of chlorophyll, conversion of starch to simple sugars and leaf proteins to soluble nitrogenous constituents. During this period leaf turns yellow, containing high percentages of soluble sugars. Now, further breaking up of sugars by respiratory enzymes has to be prevented since cured leaf must contain high sugars. This can be achieved by thermal desiccation at the subsequent stage of curing by progressively raising the temperature of the barn and lowering relative humidity by ventilation adjustments.

During the stage of Yellowing, top ventilator is left slightly open, especially during the night; bottom ventilators are left open with small gaps to continue the upward movement of air in the barn. Temperature is raised by not more than 0.5-1°C per hour reaching 40.5°C by the time the leaf becomes yellow and is ready for fixing.

During the stage of Colour fixing, the temperature raises by not more than 1.1°C every hour. Bottom ventilators are opened to approximately 10 cm at the base. Top ventilator is raised to a height of 7-12 cm from the roof.

During the stage of Lamina drying, temperature raises up to 60°C. After the moment thermometer shows 54-55°C, top and bottom ventilators are almost closed; they should be completely closed by the end of the stage.

Ventilators are closed during the whole stage of Stem (Midrib) drying. Temperature inside of the barn goes up to 71°C; it should be maintained until stem is dried. Stem (midrib) still contain large amounts of water after lamina drying and high temperatures are necessary to overcome evaporative cooling (Peele, 1995). After stem is dried, the fire is put off, but ventilators are still closed, allowing the barn to cool down itself. During the night time, ventilators and door of the barn are opened. It allows cured tobacco leaves to absorb moisture from the atmosphere and become soft. The leaf has to attain proper condition for handling. The leaf is untied from the sticks when there is proper condition preferably in early morning hours and bulked. [19]

2.5.2 Bulking, grading, and baling

Bulking is the storage of tobacco on the farm prior to grading. Leaves of different varieties must be bulked separately. The bulk should be about one meter high on a raised platform to let the air flow through the whole mass of leaves. The bulk should never be on the floor or near any material likely to give offensive odor like insecticides, fungicides or fertilizers. Bulked leaves should be turned 2-3 times prior to grading, it depends on moisture conditions. [19]

Grading (classification) can be done according to the following leaf characteristics:

a) Plant position;

b) Leaf body;

c) Leaf colour;

d) Leaf oiliness;

e) Leaf colour intensity;

f) Leaf ripeness;

g) Degree of blemish;

h) Leaf structure or texture.

For leaf classification according to its plant position and body see Tab. 4. [18]

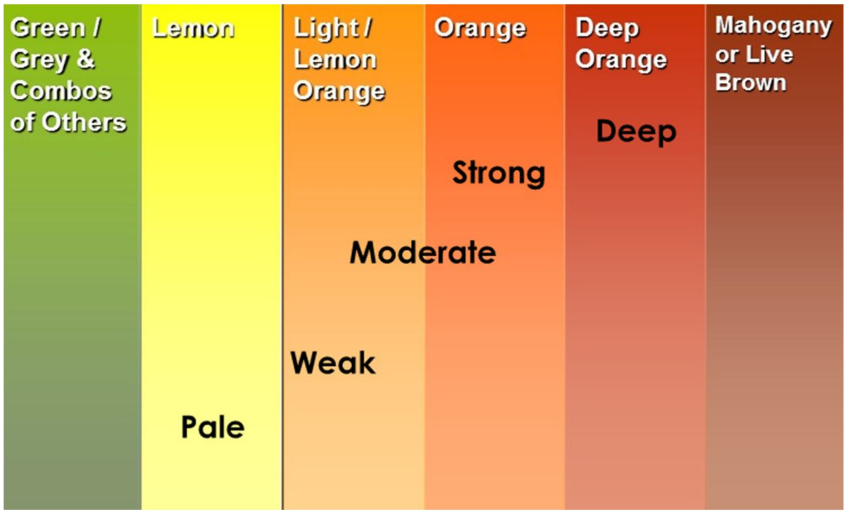
Tab. 4 Leaf position and body classification

Position	Body
Tips	Medium to heavy
Leaf	Fleshy to heavy
Thin leaf	Medium to fleshy
Cutters	Thin to medium
Lugs	Thin
Primings	Very thin to thin

According to ripeness, leaves can be unripe, immature, mature, ripe or over-ripe.

FCV tobacco is classified according to leaf colour and colour intensity. See Fig. 11.

Fig. 11 FCV tobacco colour and colour intensity classification



Source: ITC – ILTD

Ripe and mature leaves will have from lemon to deep orange colour (in some cases, mahogany) after curing and bulking is finished. Immature leaves will turn to lemon-grey or orange-grey colour, whereas over-ripe leaves will have from orange to mahogany colour. Green leaves should not be allowed for further post-harvest operations. They have to be kept in green leaf bulks divided according to its plant position. Generally, green/grey colour is typical for unripe leaves. [18, 19]

According to oiliness, leaf can be lean, oily or rich. Generally, mature and ripe leaves have more oil than unripe or over-ripe ones.

Blemish or leaf damage can be low, medium or high. Highly damaged leaves have poor structure and very crispy lamina which may be detached from the stem (midrib) during bulking.

Grading is done by hand. Leaves should be graded according to all of the characteristics. There are 4 quality grades of leaf:

1) First grade (uniform colour, low damage and blemish level (up to 20%), rich or oily);

2) Second grade (appropriate colour for leaf ripeness, medium damage and blemish level (up to 50%), lean or oily);

3) Third grade (brownish colour, high damage and blemish level (up to 70%), crispy and over-dried lamina detached from the stem);

4) Green leaves (as it was written before, such leaves should be bulked once again until they get required properties and characteristics).

During grading, it is necessary to inspect tobacco leaves for non-tobacco related matter (NTRM). This stage of NTRM control is called “Control at farm level”. Nowadays, NTRM control is one of the most crucial aspects in tobacco quality. Target is 0 NTRM! [19, 31]

NTRM is divided in 2 main categories with 2 subcategories each:

1) Inorganic NTRM:
   - Synthetic: PVC, rubber, plastic, etc.
   - Natural / mineral: metals, glass, stones, etc.
2) Organic NTRM:
   - Animal: insects, feather, animal parts, etc.
   - Vegetable: grass, seeds, paper, lint, other leaves, etc.

2.5.3 Tobacco auction platform (TAP)

After grading is done, tobacco leaves are ready to be sent to the TAP. Same grade tobacco is pressed into bails. Generally, the mass of one FCV tobacco bail is 120 kg. The better look bale has the better chance it has to be sold with a good price during the auction. Burley tobacco bales do not require specific mass or look because they are sold not on the auction but directly to a customer. [19]

In India, the marketing of FCV tobacco through auction system of started in 1984. For more than 9000 tobacco farmers in NLS area there are 5 auction floors controlled by Tobacco Board. The Board estimates the demand and regulates production of FCV tobacco to match the demand in order to ensure fair price for the produce. The Tobacco Board assists tobacco farmers in getting crop loans, quality seeds, fertilizers and other critical inputs, and counsels farmers for producing quality tobaccos to meet changing international demands. In addition, the Board conducts auctions for the sale of tobacco in a competitive and transparent environment. [18, 19, 33]

2.5.4 Aggregating godowns (AGG)

After being bought on the TAP, bales are stored in AGG or at outside handling points before being sent to various green leaf threshing (GLT) plants. Before the ERP (Enterprise resource planning system) implementation, the head clerk at the aggregating godown had to enter over 3000 records a day covering every bale. The data entry process would be repeated at every checkpoint. Not only was this tedious, it was also prone to stock reconciliation errors. [41]

ERP stands for “Enterprise resource planning”. ERP systems integrate internal and external management of information across an entire organization – embracing finance/accounting, manufacturing, sales and service, customer relationship management, etc. ERP systems automate this activity with an integrated software application. The purpose of ERP is to facilitate the flow of information between all business functions inside the boundaries of the organization and manage the connections to outside stakeholders. [4]

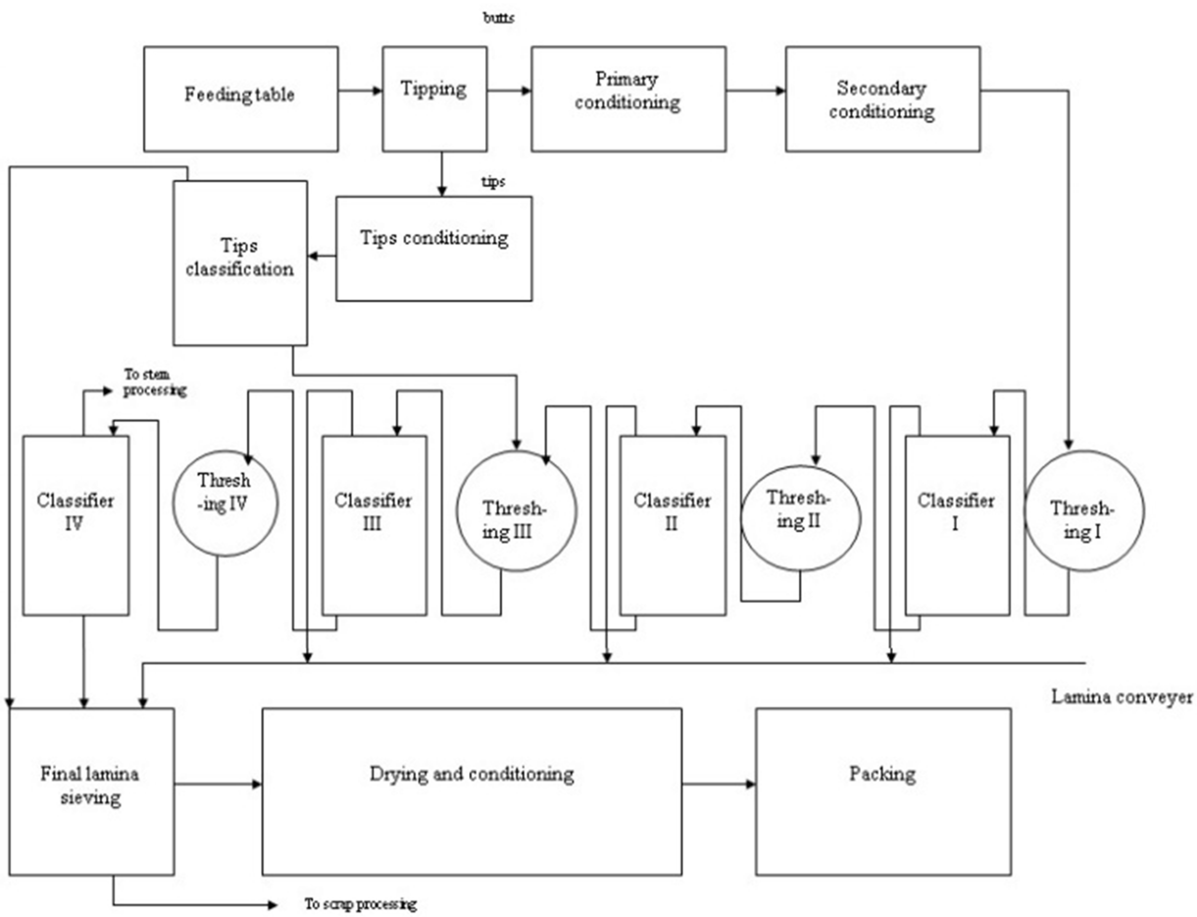
2.6 Tobacco processing

Tobacco threshing is done in the green leaf threshing plant (GLT). It is an important stage in tobacco processing, because at this stage tobacco is packed for the final consumption from its raw form.

In India, in the first half of 20th century, operations in the GLT were done manually (manual hand stemming), which were resulting in the big numbers of employees. Nowadays, the production is mechanized completely, while only blending is still done manually. Mechanized production allowed to reduce number of employees and to increase the production capacity from 80-90 tons per day up to more than 400 tons per day. [31]

The flow diagram of the GLT is given in Fig. 12. [20]

Fig. 12 GLT process flow



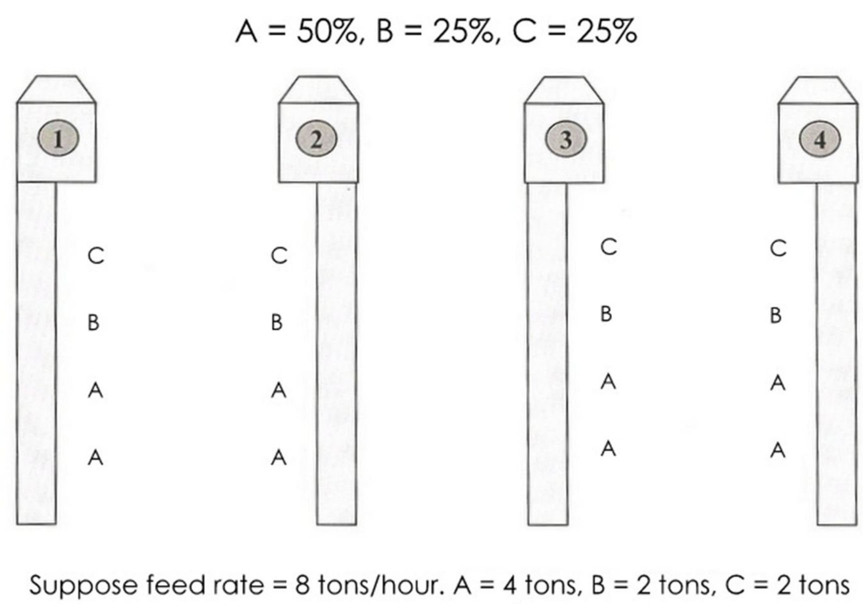
2.6.1 Green leaf storage (GLS)

Before being processed, bales are stored in the GLS. They are coming from AGG and kept in metal cages for better aeration. Different tobacco grades are stored separately from each other. [31]

2.6.2 Blending

Blending of tobaccos is the first step of many in the GLT. [31] Customer gives his requirements to producer: for example, 50% of tobacco A, 25% of tobacco B, and 25% of tobacco C. Here how it will look on the tipping machines in the GLT:

Fig. 13 Blend illustration



2.6.3 Tipping

Since the stems in the tip portion ("tips") of tobacco leaves are thin, they are cut and separated, and, generally, not sent for threshing. This process is called tipping, and it is done immediately after blending. The remaining portions of the leaves are called "butts". [20, 31]

2.6.4 Conditioning

After tipping, “butts” go through conditioning. Leaves are opened by means of hot air and steam in a conditioning cylinder. Conditioning cylinder is a rotating drum in which steam is injected passing through the tobacco leaves. Condition is done in two stages: primary and secondary. In primary conditioning, the moisture content of butts is increased up to 15-17% at the temperature of 45-50°C. The secondary conditioning is carried out to increase the moisture content up to 22% at the temperature of 60-70°C. After conditioning, the leaves are ready for threshing. The tips are also conditioned in order to match the moisture content of threshed lamina. [20, 31]

2.6.5 Feed regulation

The function of this step is to regulate the flow of the product to threshing line accurately. There are two types of regulators used: gravity feed pipe and weigh feeder. [31]

2.6.6 Threshing and Classification

The conditioned leaf is equally divided and fed into a series of threshers (normally, from 3 to 4). The function of thresher is to separate lamina and stem with minimum degradation. Thresher (Fig. 14) incorporates a cylindrical body within which a rotor is fitted with number of blades at equal distance. There are fixed teeth on the front and rear doors of the drums. The bottom half of the cylinder of thresher constitutes a removable basket (concave). Baskets with different sizes and shapes of perforations are used to suit to the type of tobacco being processed (Fig. 15). [20, 31]

Fig. 14 Thresher profile

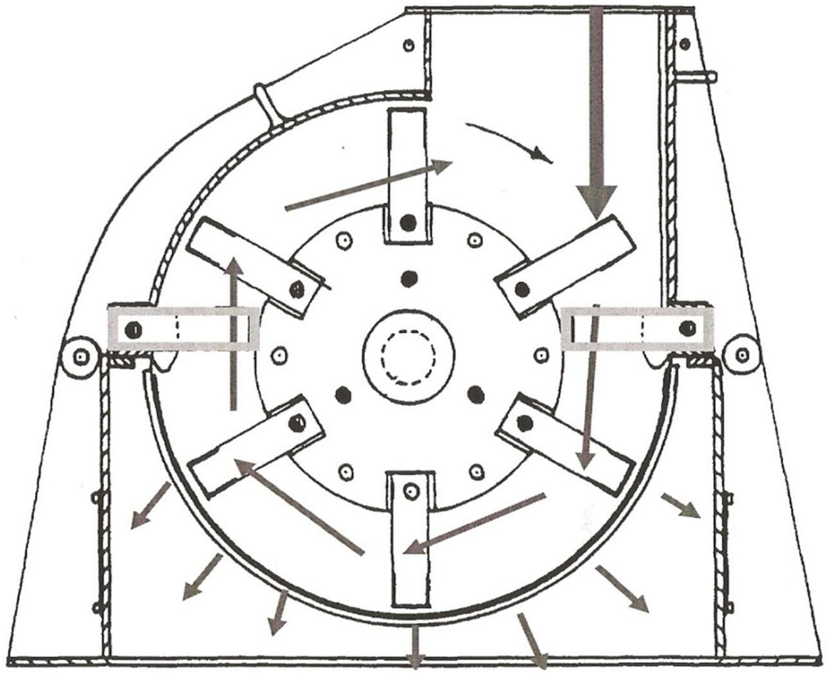
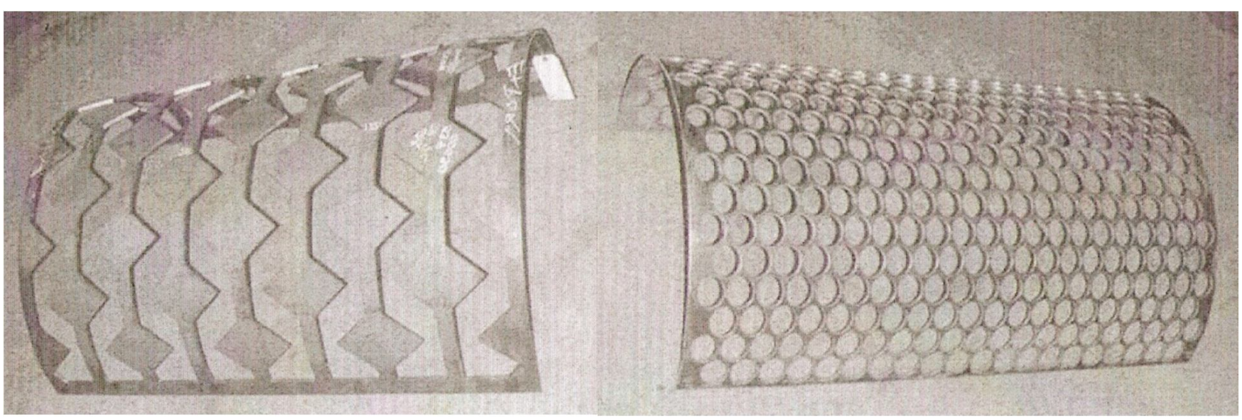


Fig. 15 Thresher baskets

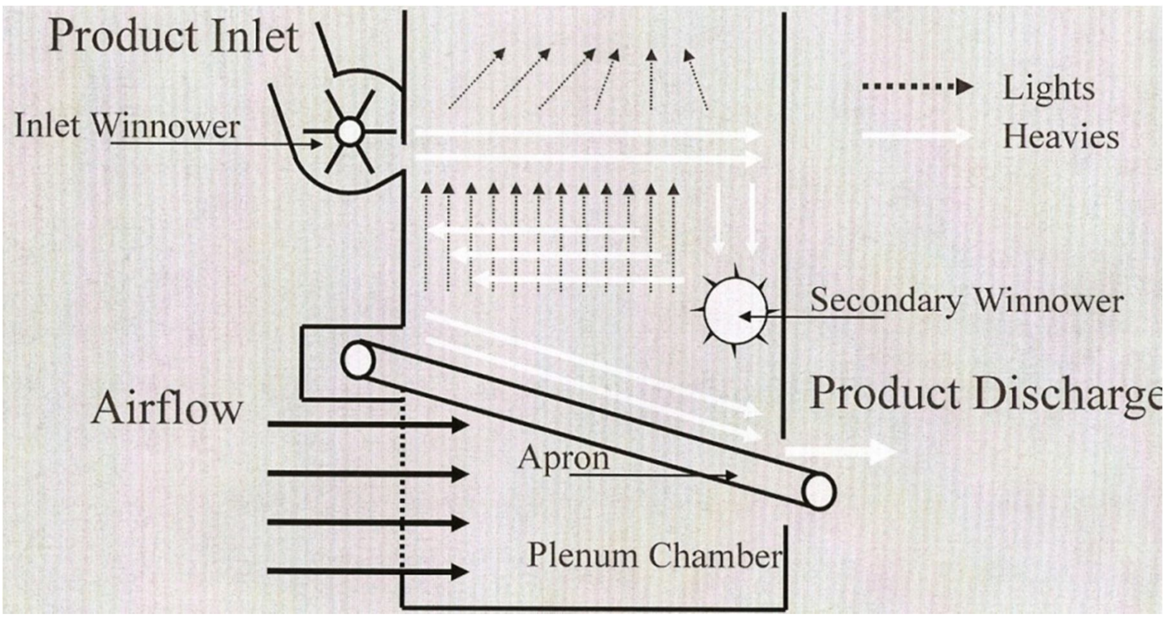


Source: ITC – ILTD

The leaves fall on the rotor of thresher and are forced to pass through the fixed teeth. At this point, the lamina is torn away from the stem, and it is taken by the rotor teeth along the direction of rotation and forced down through the perforations in the basket. The ejected product contains a mixture of lamina, stem, and unthreshed leaf. Then the threshed product is pneumatically lifted and fed into the classifier.

Classification is used to separate threshed lamina from unthreshed leaf and stems. The density difference between threshed lamina and unthreshed leaf is used for separation. Classified lamina is discharged on a conveyer and taken to the final sieving section. The heavies, which contain stems and unthreshed leaf, are sent to the next thresher. Procedure of threshing-classification (Fig. 16) is repeated until the lamina and stems are completely separated. Tips are blended with the threshed lamina and then sieved before they are fed to the redryer. [20, 31]

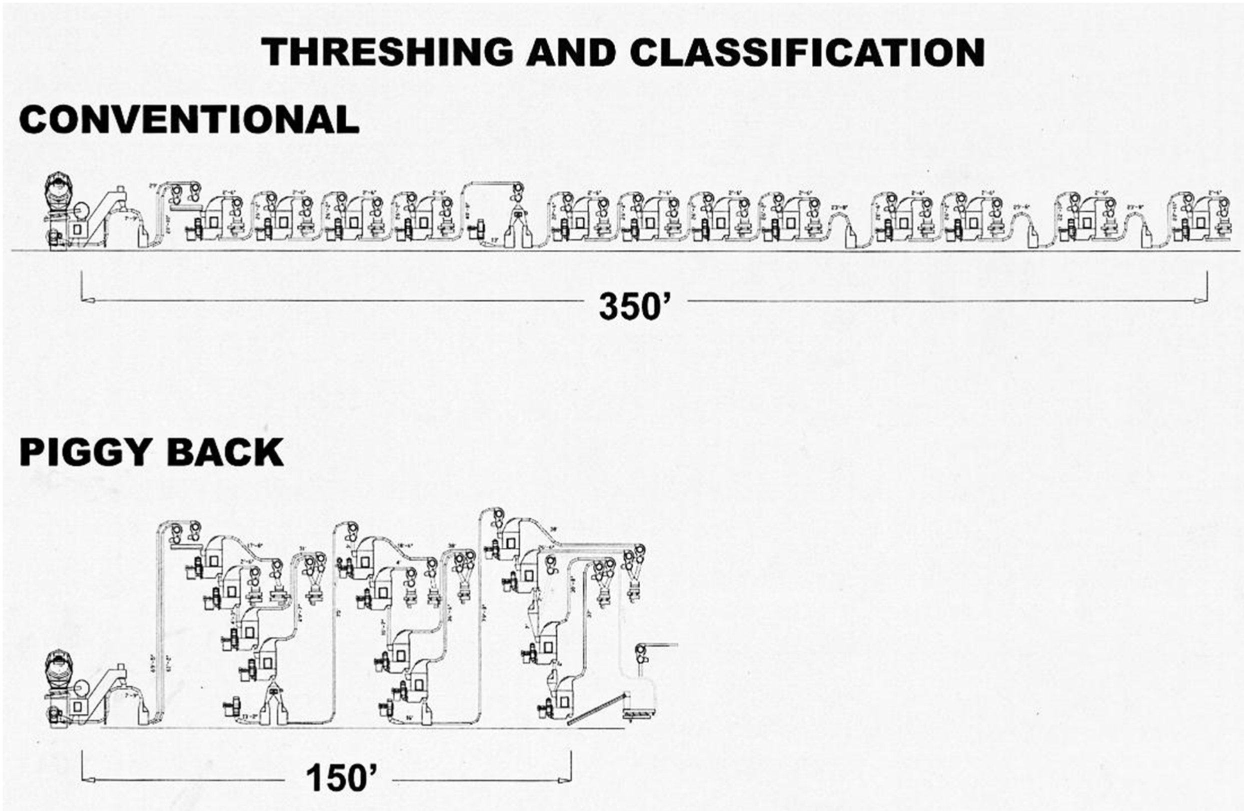
Fig. 16 Classifier operation



Source: ITC – ILTD

The old conventional stacked counterflow classifiers required a lot of energy to move tobacco products along the processing line. Also, they required a lot of space (around 350 feet in length) in the GLT. As a solution to energy and space saving problem, “Piggy back” (Fig. 17) line was introduced to production. It requires less space (total length is 150 feet) and uses natural forces of gravity to move heavies from classifier to classifier, which saves a lot of energy. [31]

Fig. 17 Conventional and "Piggy back" stacked counterflow classifiers



Source: ITC – ILTD

2.6.7 Redrying

Lamina comes from different classifiers with various moisture contents. The objective of drying is to set required moisture content of tobacco to a safe storage level. A redryer has three drying chambers, one cooling chamber, and one conditioning chamber. The mixture of threshed lamina and tips coming from the sieving is spread uniformly on a conveyor. In drying chambers, hot air is blown alternately up and down through the tobacco bed to make the drying uniform. After leaving the drying chamber, the moisture content of tobacco leaf is from 6 to 8%.The tobacco is cooled down by blowing fresh atmospheric air in the cooling chamber. Then the mixture of tobacco lamina and tips is exposed to a high humidity zone in the conditioning chamber. High humidity level is created by steam and water. The tobacco absorbs moisture and reaches an equilibrium conditions. The safe storage moisture level is from 11 to 12%. [20, 31]

2.6.8 Packing and cooling

After being redried, lamina is ready to be pressed and packed. Pressing is done by lamina press which uses hydraulic press with accurate weight control and takes filled cartons on a flow line to the end of the GLT. Also, lamina press helps to avoid degradation of threshed lamina during pressing. [31]

Redried threshed lamina (RTL) is normally packed in C-48 cartons. Volume of each carton box is 0.6 m^3. 200 kg of RTL is packed in cartons (the weight of it is about 15 kg). Polyliner or Kraft paper sheets are used as liners inside the packs based on the customer requirements or company policy. Polyliner is used in cases when tobacco is going to be sent to countries with tropical climate to preserves the product from atmosphere moisture and other factors which may change the quality of tobacco. Kraft paper liners are preferred by some customers to avoid plastic parts to go into the product. [31] However, ageing of tobacco is done with both ways of packing.

Sometimes, RTL is packed by pressing between two wooden boards and tied with 2-3 galvanized iron (GI) wires and covered with a gunny bag. This type of packing is called “bale board pack”. [20]

After packing is done, tobacco is placed in the storehouses for post-process cooling. Cooling of processed tobacco may take up to 7 days (with single layered rack cooling). Pressed and packed tobacco product is called “tobacco cake”.

Another tobacco products, such as stems and tobacco scrap (small lamina particles), are packed separately from lamina. [31]

2.6.9 NTRM control

As it was said before, NTRM (non-tobacco related matter) control is a very important process during tobacco post-harvest operations. [31] In the GLT it can be done by:

- Metal detectors;
- Rare earth magnets;

- Desanedrs;
- Fluff removers;
- Optical NTRM sorters;
- etc.

2.6.10 Quality parameters and control

The quality analysis in the GLT is a laborious process. Around 25% of the workers of the factory are used for the quality testing operations. Like moisture content and temperature of the products during processing, particle size of lamina, and stem content in lamina are the important quality parameters to be measured in the GLT. The details of the quality analysis are given in Tab. 5. After the tests, 3 kg sample becomes scrap (almost powder) and cannot be reused. [20, 31]

Tab. 5 Quality parameters and test procedures

Quality parameter	Test interval, min	Sample size, g	Procedure
LAMINA			
Partical size	20	2500-3500	Degradation shaker
Stem content	20	2500-3500	Stem tester
Moisture	5	50	Brabander (quick moisture analyzer) / Hearson oven
STEM			
Length	60	250	Stem length board
Diameter	60	250	Rotap tester
Moisture	30	50	Brabander (quick moisture analyzer) / Hearson oven

2.7 Tobacco storage

Tobacco storage is an essential part of tobacco production. During storage, tobacco is ageing; the chemical changing occur improving the taste and aroma of the tobacco. Also, the storage of the tobacco serves another very useful purpose, which is prevention of a crop "failure" by keeping large quantities of tobacco in warehouses, since the quality of tobacco may vary significantly from year to year.

2.7.1 Warehousing

The packed tobacco products are stored in warehouse complexes for at least 6 months before used for cigarette production. During warehousing, ageing or mellowing of tobacco takes place. It brings many desirable chemical changes to the product. One of the main tasks is to protect the packed products from pests and mould.

In NLS region of India, there are around 20 warehouse complexes, which means approximately 230 compartments (godowns) overall. In 2002-2003, the whole mass of tobacco stored in warehouse complexes was around 80,000,000 kg. In 2011, it has increased up to 150,000,000 kg. One warehouse complex requires staff of from 5 to 10 workers and from 2 to 8 members of pest control agency. [36]

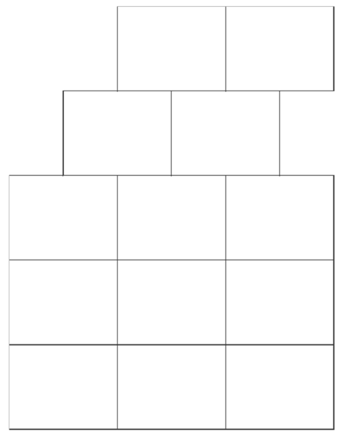
Purchased tobacco is graded by either by a government grading system or by a company grading system. When a company purchases tobacco, it is immediately "regarded" according to the company's own quality assessment. There are the following main grade criteria:

- Tobacco type;
- Geographical location;
- Date;
- Company grade.

Different grades are stored separately from each other, as well as stems and scrap should be stored separately from lamina. [36]

In warehouses, packed tobacco products are stored in pair rows, up to 5 levels at height (Fig. 18). Sometimes, they might be stored up to 6 levels, but in this case tobacco from the bottom level receives more stress and becomes very hard. It is required to place tobacco packs in the following order:

Fig. 18 Placement of tobacco packs



As it was said in description of Packing and cooling processes in the GLT, tobacco products are put in C-48 carton. A standard 20 feet container fits 48 of these cartons; this is why these boxes are called C-48. Paired rows of C-48 carton are placed on wooden platforms for better air flow. Distance should be 2 feet between them and 1 meter from the walls. As a matter of fact, the reactions occurring in the FCV tobacco can become so violent at elevated moisture that the entire tobacco cake can ignite. In this case, for sufficient ventilation of the godown there are a special mesh door (20 mesh/inch, also prevents from cigarette beetle coming from the outside) and ventilation windows in the walls, which are protected from rainfalls. [28, 36]

2.7.2 Mould and pest control

During storage, it is very important to prevent tobacco from mould and pests. Improper storage conditions may lead to great loss of tobacco due to its damage done by mould or pests.

According to Dr. Sam Samfield, mould damage is one of the most disastrous things that can happen to tobacco during storage, and yet it is the easiest to prevent. There are two reasons why mould can appear: high moisture content and high temperature. High moisture may be the result of improper redrying, high humidity during storage, or leaking storage roofs or windows. High humidity level may be caused by poor air circulation in a godown. [28] In summary, mould damage may be prevented by:

- Proper redrying of the tobacco (no condensate is required to be in the redryer);
- Proper godown construction;
- Rigid storage godown maintenance program.

Insect damage during the tobacco storage is much more difficult to prevent than mould damage. There are approximately 20 insects consuming tobacco, but only two are of importance: the cigarette beetle (*Lasioderma serricorne*) (Fig. 19) and the cigarette moth (*Ephestia elutella*). The life cycle of both of them is the same: egg, larva, pupae, and imago (in approximately 56 days). However, the physical size of the moth prevents its entry into the interior of the godown. Because of its large size, the tobacco moth is much easier to control than the cigarette beetle. [28, 36]

Fig. 19 Tobacco damaged by the cigarette beetle (imago and larvae)

Source: Degesh, Inc.

Nowadays, the most efficient way to kill tobacco pests is to use fumigants. Insecticides generally kill the imago only and kill by contact or residual activity, while fumigants kill all stages of the insect and penetrate throughout the tobacco mass. Fumigants are applied in the gas phase only: for example, gas phosphine is used at atmospheric pressure.

There is a special protocol called HIMILO (Hygiene and Infestation Management In Leaf Operations), published by the Indian Leaf Tobacco Division (ILTD) of the Indian Tobacco Company (ITC). [36] This protocol is considered to be the best warehousing practice. HIMILO-2011 includes the following technical procedures:

TP-1. Warehouse structure and standards;

TP-2. Insect screening of warehouses and cool storage;

TP-3. Warehouse hygiene;

TP-4. The Serrico Trap (a monitoring device for tobacco beetle);

TP-5. Tobacco beetle management at farmers premises (only at project areas);

TP-6. Tobacco beetle management at TAP’s (only at project TAP’s);

TP-7. Tobacco beetle management at AGG;

TP-8. Insecticide (hard surface) spraying in warehouses and factories;

TP-9. Insecticide fogging and misting in integrated pest control;

TP-10. Phosphine fumigation of tobacco;

TP-11. Quarantine fumigation of green leaf bales;

TP-12. Fumigation sheet integrity;

TP-13. Emergency planning (accident phosphine release in the local environment);

TP-14. Phosphine gas monitors;

TP-15. Drager tubes for phosphine monitoring;

TP-16. Protective cover sheeting (infestation barrier);

TP-17. Freight containers for tobacco export;

TP-18. Track back system for stock management and customer comments.

Cigarette beetle population management monitoring includes preventive and control measures.

Preventive measures should be done during receipt control and control of unwanted tobacco or by sanitation (warehouse keeping and hygiene) and surface/space treatment. As it was said before, special mesh doors and windows (20 mesh/inch) isolate stored tobacco products from cigarette beetle coming to the godowns from the outside. Surface cleaning should be done daily, while stacks/drains/surroundings cleaning are done when needed. Scrap collection and its fumigation are done daily. [28, 36]

Control measures include monitoring and fumigation. Monitoring of adult beetle population is done by using Serrico Traps (Fig. 20), in which both sex pheromone lure and food attractant lure are used.

Fig. 20 Serrico Trap

Source: Fuji Flavor Co., Ltd., http://www.fjf.co.jp/en/ecomon/product/serrico/

Serrico traps are placed in the central storages. One trap covers 30 feet radius, which means that the placement of traps should be done 50-60 feet from each other, head height on stand. Monitoring of traps is done daily, while reporting is done weekly; replacement of traps is done every 30 days. For classification of weekly monitoring results see Tab. 6. [36]

Tab. 6 Weekly monitoring results classification

<table>
<tr><th>Beetle/trap per week</th><th>Level of infestation</th><th>Action</th></tr>
<tr><td>0-5</td><td>Low</td><td>Check and improve cleaning and screening: stacks, floors, walls, and mesh screening</td></tr>
<tr><td>6-10</td><td>Moderate</td><td rowspan="2">Check and improve cleaning and screening;

Insecticide spraying in warehouse, Insecticide fogging and misting in Integrated pest Control;

If beetle count reduces, continue cleaning for improving warehouse hygiene;

If beetle count increases, inspect stocks, check for life stages and decide on requirement of fumigation;

Check the stacks around the Serrico Traps showing the highest counts.</td></tr>
<tr><td>11-15</td><td>Heavy</td></tr>
<tr><td>>15</td><td>Very heavy</td><td>Inspect stocks for life stages and decide on requirement of fumigation.</td></tr>
</table>

Source: ITC – ILTD

Fumigation should be done only by the skilled staff! This is a very important and dangerous for human health process. During fumigation, warning notices are to be placed on the stack sheet and godown door. After picking the infested stack, it is covered with a special sheet, which should be inspected before using. Sometimes, the whole godown needs to be fumigated. Fumigant (Aluminium phosphine tablets) is placed under the stack; dosage is 3 grams per m^3 of stack volume. After placing the fumigant, stack sheet is fixed by double row sand snakes to prevent gas leak. It is necessary to provide phosphine leak detection during the fumigation process. Phosphine concentration should be minimum 200 ppm for 96 hours inside of the tobacco cake. Overall, the duration of the fumigation is 10 days minimum. [36]

2.7.3 Ageing

According to Akehurst, ageing is the final stage in the creation of optimum smoking quality. The term "ageing" refers to changes occurring during storage of tobacco between GLT processing and cigarette production. The leaf develops its full flavour, becomes more aromatic and usually darkens in colour. The fuller bodied the tobacco, the more marked will be the ageing changes. All tobaccos improve to some extend in storage by losing the sharp taste of freshly cured tobacco and a general smoothing of its rough edges. Even unripe tobacco can be improved with ageing, but it will still be the lower quality leaf comparing to the better leaf. [2]

Not only time is the important factor for producing well aged flue-cured tobacco; temperature and moisture content during storage are also very important. Natural ageing is accomplished by packing tobaccos at moisture content from 10 to 13% and a packing density ranging from 16 to 20 lbs/feet^3 for a period of 6-24 months at ambient temperature. Low stalk position leaves (primings and lugs), as well as scrap, generally complete the ageing process within 6 months, while for mid-to-upper leaves (cutters, thin leaf, and leaf) it takes from 12 to 24 months to age. It is the seasonal temperature instability that is responsible for the change in aroma from greenish dried hay-like to a pleasant, complex mellow aroma and an improvement in smoke characteristics, such as smoke taste: from a raw, disagreeable taste to a milder, smoother, more rounded flavour. [8]

The chemistry occurring during the ageing process is a series of reactions involving sugars and amino acids. Asparagine, glutamine, and proline (the principal amino acids of FCV tobacco) react with sugars to develop aromatic products known as melanoids. This transformation process results in smoothing and mellowing of taste characteristics and is further responsible for the darkening of tobacco with time. [22]

According to analysis report from "American Tobacco" collection from 1989, chemical changes during ageing period of 30 months are shown in the Tab. 7.

Tab. 7 Chemical changes during ageing

Component	Before ageing, %	After ageing (30 months), %
Priming grade		
Total nitrogen	2.07	2.07
Amino nitrogen	0.287	0.22
Nicotine	1.46	1.4
Total sugars	10.6	8.3
Water soluble acids	3.24	3.77
Mid-stalk grade		
Total nitrogen	2.13	2.13
Amino nitrogen	0.207	0.145
Nicotine	2.28	2.16
Total sugars	16.6	14.2
Water soluble acids	3.56	4.05

Source: “American Tobacco” report, 1989

pH of the tobacco product reduced by 0.1% in both grades after ageing.

Carbonyl compounds are also considered to have a bearing on aroma in a wide variety of processed products such as popcorn, roasted peanuts, and cooked beef. As FCV tobacco undergoes a mild heat treatment during ageing, carbonyls are generated and improve aroma of tobacco. From 100 mg per 100 g in a green leaf stage carbonyl concentration goes up to 840 mg per 100 g in aged tobacco (after 1 year). [9]

In general, tobacco ageing is characterized by physical and chemical changes in tobacco, which increase its aroma and smoking characteristics. Ageing may be affected by improper storage conditions and packing.

2.7.4 Container loading and shipping

After proper warehousing and ageing, tobacco is ready to be loaded into containers and shipped to a customer. Each tobacco pack should have a card with the following information:

- Seller;
- Buyer;

- Delivery address;
- Name of goods;
- Contract number;
- Country of origin
- Gross and net weight.

After container loading at the warehouse complex, it is necessary to place a Serrico Trap in each container for the final monitoring of the cigarette beetle population. Before shipping, containers are checked once again and sealed. Since that moment, tobacco is ready to be sent to a customer for cigarette production. [36]

3. AIM OF THE THESIS

The aims of this Diploma Thesis are to study post-harvest operations, processing, storage, and ageing aspects of FCV tobacco, to evaluate the changes during tobacco ageing process under different conditions (using Polyliner and Kraft paper as liners for packing), and to compare obtained results.

4. MATERIALS AND METHODS

4.1 Materials

Four samples of the FCV tobacco, grown in NLS region, harvested and cured in 2011 and 2012, were provided by the ILTD division of ITC. The samples were of the closest equivalent of grades packed for two different customers using two different types of liners for C-48 cartons: Polyliner and Kraft paper. The mass of each sample was 500 grams.

Four samples are named in the following way:

Tab. 8 Samples of the FCV tobacco

Sample #	Liner	Harvesting year	Sample name
1	Kraft paper	2011	K11
2	Polyliner	2011	P11
3	Kraft paper	2012	K12
4	Polyliner	2012	P12

Samples were compared in the following way: K11 with P11, and K12 with P12. Comparison of K11 and K12 or P11 and P12 would not be correct, since tobacco quality depends on weather, soil, curing, etc. conditions and varies from year to year. That is why tobacco samples from the same year were compared.

4.2 Organoleptic analysis

Organoleptic analysis was done according to aroma, colour and its intensity, elasticity, texture, and oiliness of the tobacco. Since organoleptic parameters are very important, it is necessary to learn how to evaluate them.

Under supervision of PSRVS VITHAL, M.Sc., I was trained how to evaluate basic parameters and criteria of aged tobacco. Tobacco aroma may be juicy, sweetish, harsh, fruity, etc. Tobacco colour may vary from lemon to brown; it can be uniform or not. According to oiliness and elasticity, tobacco may be oily, dry, crispy, soft, gummy, etc.

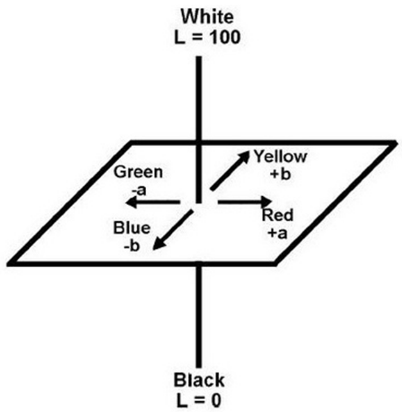
Fig. 21 Aged FCV "tobacco cake" inspection

4.3 L*a*b analysis and Gas Chromatography – Mass Spectrometry

Image analysis of L*a*b parameters and Gas Chromatography – Mass Spectrometry (GC-MS) were done in the Institute of Chemical Technology in Prague with assistance of Ing. František PUDIL, CSc. Tests were carried out at Department of Water Technology and Environmental Engineering (217) and Department of Food Analysis and Nutrition (323).

L*a*b colour space is known for its uniformly and precise determination of the colour. "L" shows the luminance (lightness) of the material on the scale from 0 (black) to 100 (white); "a" scale ranges from negative (green colour) to positive (red colour) values, and "b" scale ranges from negative (blue) to positive (yellow) values.

Fig. 22 L*a*b colour space



Source: www.sites.google.com/site/sachidanandabs/colorspace

For the analysis the following equipment and software were used:

- Standard fiber optic spectrometer Avantes AvaSpec-2048;
- AvaSoft, ver. 7.4;
- Microsoft Office Excel 2010;
- StatSoft STATISTICA, ver. 7.0.

L*a*b parameters were measured 10 times for each sample, since "tobacco cake" has lighter and darker leaves. Prior every measuring session, spectrometer was calibrated.

Fig. 23 Measuring L*a*b parameters

Gas Chromatography – Mass Spectrometry method was used to identify the aromatic composition and volatile compounds of the tobacco samples. GC-MS analysis was performed with Fisons Instriments (Italy) GC-8000 with mass detector MD-800. The GC chromatographic column consisted of a Supelcowax fused silica capillary column (30 m length; 0.32 mm diameter; 65 µm film thickness; blue/plain hub). Helium was used as a carrier gas.

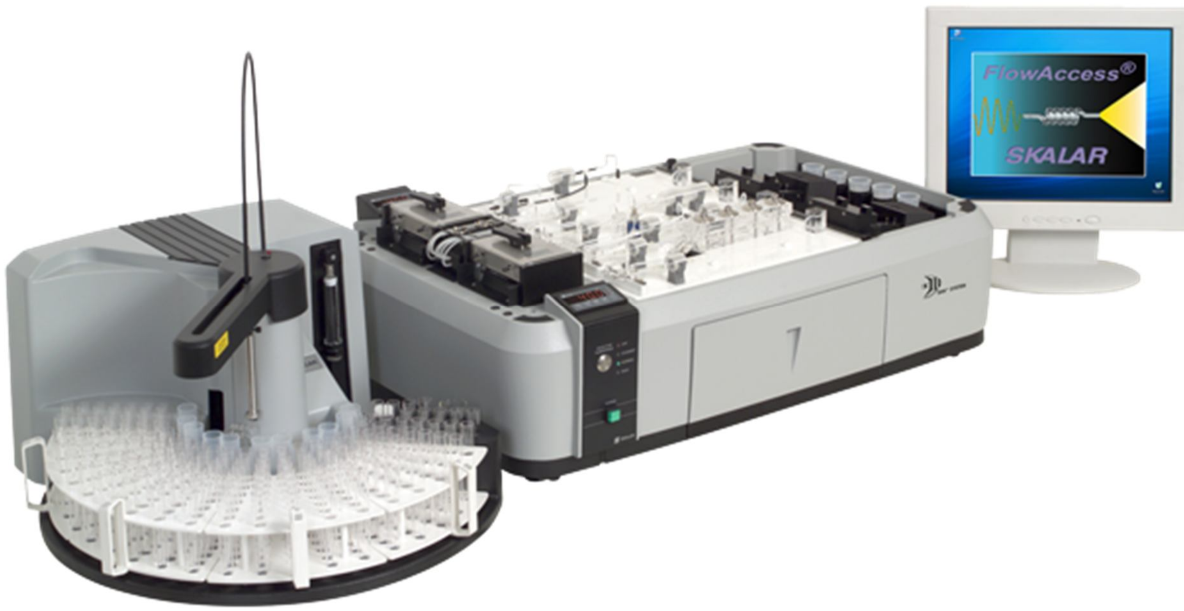
The beginning of the cycle was isotherm (50°C) for 3 minutes, and then the temperature was constantly increasing by 3°C per minute, reaching 250°C. Since elevation temperature and injection of inert gas, absorbed molecules travel through the column with different speed. Smaller molecules travel faster through the column. Retention time is the time required for a molecule to go through the column.

Graphs with retention time and corresponding specters were analyzed, and identified chemical compounds of the tobacco samples are presented below. For identification of compounds, Library of chemical compounds and specters NIST (National Institute of Standards and Technology, USA) was used.

4.4 Total alkaloids, reducing sugars, and oven volatiles determination

Simultaneous automatic Determination of Total Alkaloids (TA) and Reducing Sugars (RS) in Tobacco by Colorimetric Detection Using the Skalar flow analyzer, and Moisture Determination of Tobacco Products by Oven Drying were done in Quality Assurance Laboratories of Philip Morris ČR a.s., Kutná Hora, according to Internal Standards Q (KH) 0202 and Q (KH) 0210. Analyses were done with assistance of Ing. Jiří ŠLITR, Ing. Marcel BILINKIEWICZ, and Renata PIPKOVA.

Fig. 24 Skalar flow analyzer



Source: http://www.skalar.com

An acidic aqueous tobacco extract is analyzed calorimetrically by means of a continuous flow analyzer. During the analytical cycle, the sample is distributed into four channels in order to determine total alkaloids and reducing sugars, after dialysis purification, by derivatization. Also, this test is applicable to aqueous extracts.

Alkaloids with a pyridine nucleus are determined by their reaction with cyanogen chloride in presence of sulfanilic acid. A yellow imine derivative is formed with a maximum absorption at 460 nm. Reducing sugars are determined by their reaction with p-hydroxybenzoic acid hydrazide. In alkaline medium, at 85 °C, a yellow osazone is formed with a maximum absorption at 410 nm.

Sample requirements:

- Tobacco weight recommended: 6 to 8 g;
- Tobacco weight recommended per determination: 0.5 g;
- Number of determinations normally performed: 1.

Man hour per determination (workload): 15 min.

The determination of the concentration of alkaloids and reducing sugars carried out by comparing the absorptions measured for each of these products with those measured for standard solutions containing known concentrations of nicotine hydrogen$^{(+)}$-tartrate and glucose fructose.

A reference tobacco extract (monitor) of known concentration is used to check that the instrumentation is in proper working order.

Sample preparation:

- Grind the tobacco to pass through a 1.0 mm mesh and place it in a tin for Oven Volatiles (O.V.) determination. The O.V. determination must be carried out on 7-8 g tobacco.
- Weigh out, to the nearest 0.001 g, 0.48 to 0.52 g ground tobacco and transfer it into a 250 ml Erlenmeyer flask.
- Add 100.0 ml 5% acetic acid with a 100 ml automatic burette, shake for 30 minutes.
- Filter, using a pleated filter, and take an aliquot of the extract for analysis.
- The tobacco extracts must be analyzed within 48 hours (store at 5°C).
- Prepare one or two monitor tobacco extracts.

Setting up of the analyzer:

- Check that the bottles, containing the chemical reagents, are filled.
- Make sure the tubes are clean and have no leaks.
- Rinse the system with water for 10 minutes and then with the reagent solutions until the baseline is stable (at least 20 minutes).

Testing procedure:

- Refer to the operating manual of the autoanalyzer to ensure correct setup, use and maintenance.
- Ensure that the sample sequence on the sampler tray is correct.
- Start the automatic measuring procedure.
- The sequence can be divided in two phases:
  - calibration and checking of the monitor extract and control standard;
  - analysis of sample extracts.

Calculation:

The analytical results (peak heights) are automatically processed by the system. For each sample, the system calculates the different concentrations on the basis of the five point calibration curve. The raw values are then corrected by: dry weight basis. The final results are expressed in % weight of dry tobacco, taking into account the exact weight and the O.V. value of each sample.

In past, levels of nitrates (NO_3) and ammonia (NH_3) were measured, but nowadays this information is not as useful and helpful for cigarette production, as it was before.

5. RESULTS AND DISCUSSIONS

Despite the fact that tobacco samples are of the closest equivalent of grades, tobacco is a biological material and may be harvested during slightly different level of ripeness, which means that there will be no completely equal “tobacco cakes”. Tobacco is very sensitive for internal and external conditions during its post-harvest operations.

Results of comparisons of the given tobacco samples are shown is figures and tables below.

5.1 Organoleptic analysis results

According to comparison of organoleptic parameters of tobaccos from 2011, the following results were obtained:

Tab. 9 Comparison of organoleptic parameters of the samples from 2011

Parameters	Sample	
	K11	P11
Aroma	Typical, deep, strong, sweetish	Typical, mild, sweetish
Colour	From orange to dark brown	From orange to brown
Elasticity, Oiliness	Dry, crispy	Less dry, soft

K11 sample has stronger aroma in comparison with P11 sample. Also, K11 sample is slightly darker. According to elasticity and oiliness characteristics P11 sample is softer and less dry.

Probably, stronger aroma of the K11 sample is the result of more opened storage conditions inside of the C-48 carton with Kraft paper liner, since air can go through the “tobacco cake” easier forcing the process of ageing. Also, higher level of reducing sugars in the K11 sample can be the reason of such strong aroma. To ensure this, levels of TA and RS were measured.

P11 sample is less dry and softer in comparison with K11 sample. The reason of it may be more stable moisture conditions inside of the C-48 carton, not depending on weather conditions during the ageing.

Colour is almost the same, except of some areas of K11 sample where tobacco is dark brown. For more precise results of colour comparison L*a*b analysis was performed.

According to comparison of organoleptic parameters of tobaccos from 2012, the following results were obtained:

Tab. 10 Comparison of organoleptic parameters of the samples from 2012

Parameters	Sample	
	K12	P12
Aroma	Typical, mild, sweetish	Typical, mild, from sweetish to fruity
Colour	From orange to deep orange	From yellowish to orange
Elasticity, Oiliness	From oily to crispy, soft	Oily, soft

Aroma of the K12 sample is slightly deeper; however, both samples have mild and sweetish aroma (the P12 sample had even fruity aroma). As it was said before, more opened storage conditions inside of C-48 carton with Kraft paper liner may result in deeper aroma. Also, the less difference in aroma between the samples from year 2012 may be the result of closer levels of reducing sugars, in comparison with the samples from year 2011, since ageing took one year.

The P12 sample is oily and soft. The K12 sample is slightly crispier, however soft as well.

In general, the colour of both samples is almost similar. However, the K12 sample has deep orange leaves, and P12 has yellowish leaves. For more precise results of colour comparison L*a*b analysis was performed.

Fig. 25 The K11 sample

Fig. 26 The P11 sample

Fig. 27 The K12 sample

Fig. 28 The P12 sample

5.2 L*a*b analysis and Gas Chromatography – Mass Spectrometry results

Since the colour of the samples from the same year looks almost similar, to understand the precise colour difference between the samples L*a*b analysis was performed. Each parameter was measured 10 times. The following charts show comparisons of “L” parameter values between K and P samples from different years.

Fig. 29 Luminance of the samples from 2011

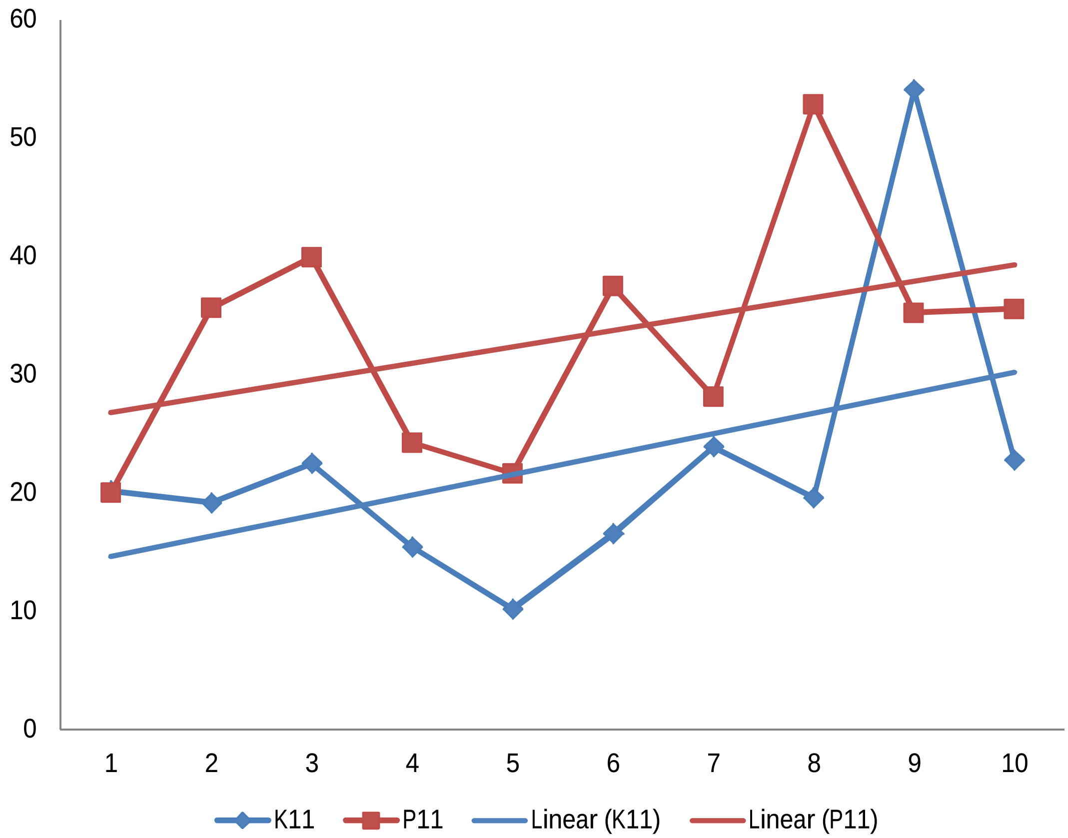
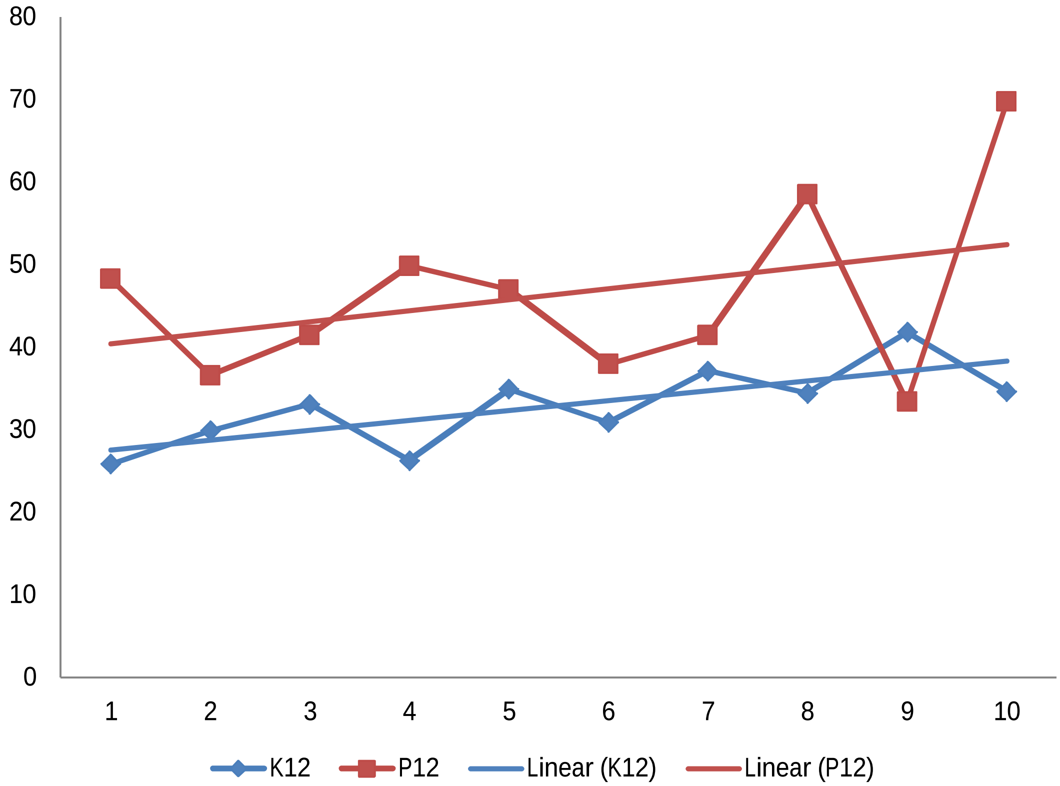


Fig. 30 Luminance of the samples from 2012



The higher L values are, the lighter material is. Both P11 and P12 samples have higher luminance, comparing to the K11 and K12 samples. Darker colour of the samples aged in C-48 cartons with Kraft paper liner may be the result of faster ageing process.

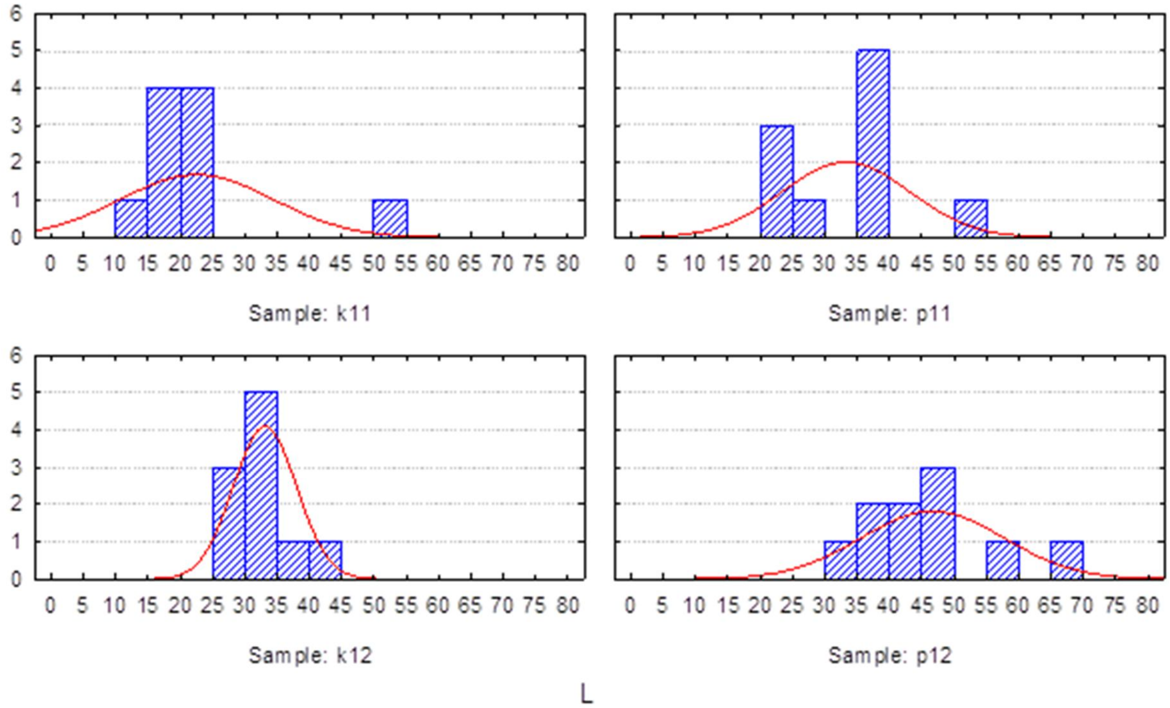
Average values of L*a*b analysis results are shown in Tab. 11. Full tables of 10 measurements for each sample can be found in the Appendix.

Tab. 11 L*a*b analysis results

Parameters	Sample			
	K11	P11	K12	P12
Average L	22.435	33.075	32.923	46.428
Average a	9.92	12.446	12.612	11.159
Average b	26.021	24.369	28.123	31.496

L*a*b analysis results were processed in StatSoft STATISTICA software to compare the colour uniformity of the samples. See Fig. 27.

Fig. 31 Uniformity of luminance of the samples



From the results, we can say that the colour of the K12 sample is more uniform in comparison with the P12 sample. Both K11 and P11 samples have low uniformity of colour. However, if we compare the changes between samples from different years, aged in the same conditions, we can see that colour uniformity of tobacco aged in C-48 carton with Kraft paper liner may change during the ageing process. But this information may vary, since the sample size was 500 grams out of 200 kg “tobacco cake”.

GC-MS analysis results are shown in the Fig. 28 and 29. Many volatile compounds were detected during this experiment. The list of compounds with highest peaks is shown in Tab. 12.

Fig. 32 GC-MS analysis of volatile compounds of the samples from 2011

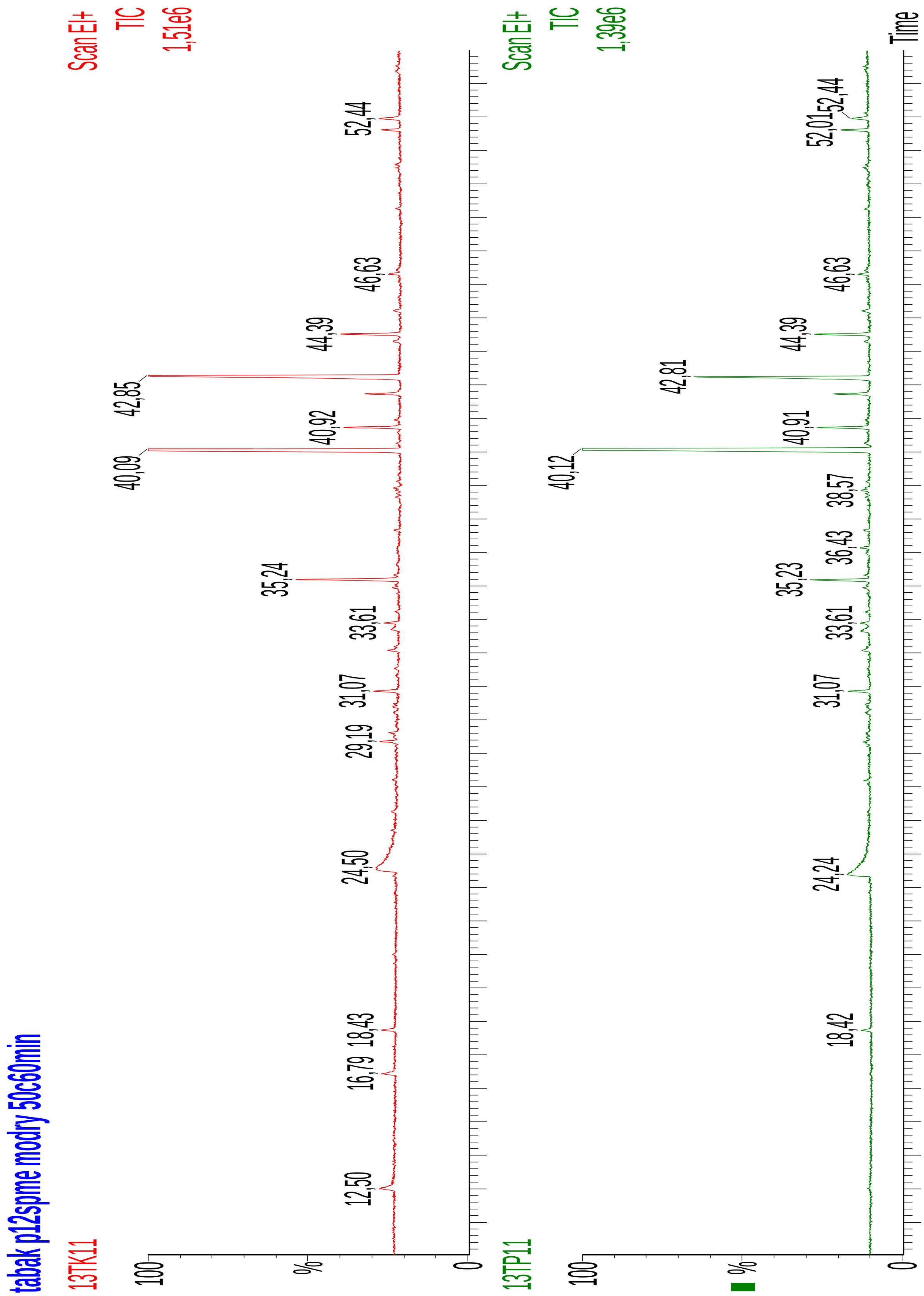
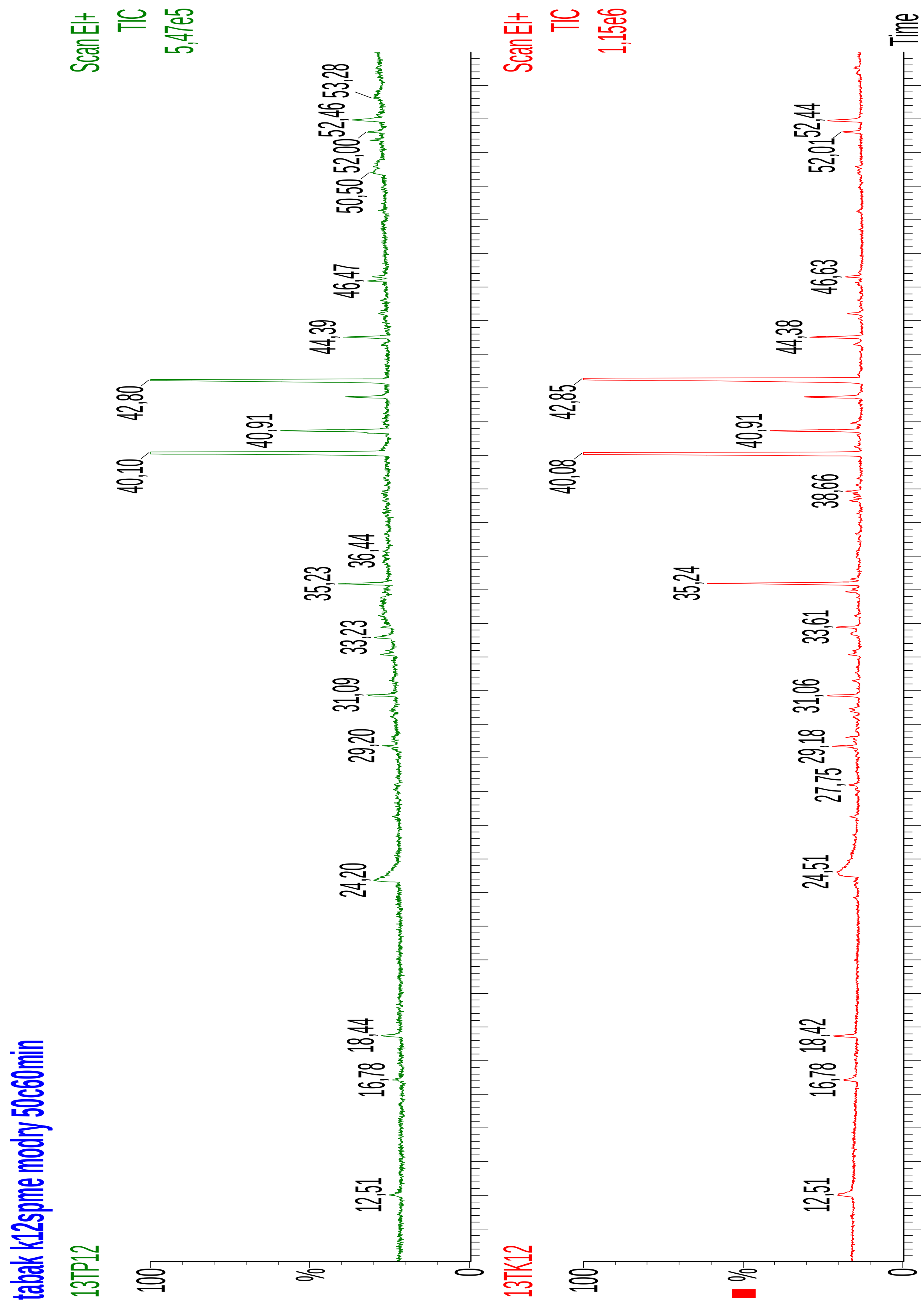


Fig. 33 GC-MS analysis of volatile compounds of the samples from 2012



Tab. 12 Volatile compounds of the samples

Peak, time, min	Compound
12.5	aliphatic
16.79	aliphatic
18.43	aliphatic carbonyl
24.50	acetic acid
29.19	aliphatic carbonyl
33.61	2H-pyran-2-on
35.24	*unidentified*
36.24	sesquiterpenic carbonyl
40.09	nicotine
40.92	benzyl alcohol
42.17	2-phenylethanol
42.85	aliphatic alcohol
44.39	acetyl pyrrole
46.63	aliphatic
52.01	aromatic aldehyde
52.44	heterocyclic
55.20	aliphatic
56.54	aliphatic alcohol

The results of GC-MC analyses show quantitative and quality biochemical composition of the samples. The highest peaks on all chromatograms are the peaks of nicotine, the main alkaloid of the tobacco leaf. Second highest peaks are the peaks of aliphatic alcohol with retention time of 42.85 minutes. Also, following peaks look sizeable: the peak of unidentified compound with retention time of 35.24 minutes and the peak of benzyl alcohol with retention time of 40.92 minutes.

Comparing quality and quantity of the peaks, we can say that type of liner does not affect biochemical composition of the tobacco leaf, which means that both types of packing can be used without unwanted changes in the product.

5.3 Total alkaloids, reducing sugars, and oven volatiles determination results

Results of TA, RS, and OV determination, according to Internal Standards Q (KH) 0202 and Q (KH) 0210, Philip Morris ČR a.s., Kutná Hora, can be found in Tab 13. Results of TA and RS levels were corrected according to percentage of oven volatiles. After correction, the amount of TA and RS on dry weight basis was determined.

Tab. 13 TA, RS, and OV determination in the samples

Parameter	Sample			
	K11	P11	K12	P12
TA, %	2.81	3.17	2.82	3.00
RS, %	10.58	7.95	9.90	9.05
OV, %	8.80	9.30	9.20	8.50

All of the samples have normal levels of TA and RS, according to norms for NLS FCV tobacco (1.5-3.5% of nicotine, 7-18% of reducing sugars).

Both samples aged with Kraft paper liner have lower level of nicotine comparing to samples aged with Polyliner; however, the level of reducing sugars is higher. As it was said before, the amount of nicotine vs. sugars is usually an inverse relationship. As I assumed during organoleptic analysis, the difference in RS levels between K12 and P12 samples is not that big, whereas the level of RS in the K11 sample is much higher than in P11 sample (it may be the reason of such difference in aroma between these two samples).

6. CONCLUSIONS AND RECOMMENDATIONS

Based on the results in this diploma work, the following conclusions can be done:

- ✓ In both cases, levels of TA and RS stay in ranges of norms. However, tobacco aged in C-48 cartons with Kraft paper liner has higher level of RS.
- ✓ Aged for two years with Kraft paper liner tobacco has strong and deep aroma in comparison with tobacco stored with Polyliner. In both cases, tobacco aged for two years have stronger aroma than tobacco aged for one year.
- ✓ Comparing the changes between samples from different years, aged in the same conditions, we can see that colour uniformity of tobacco aged in C-48 carton with Kraft paper liner may change during the ageing process. But this information may vary, since the sample size was 500 grams out of 200 kg “tobacco cake”.
- ✓ Comparing quality and quantity of the peaks on chromatograms, we can say that type of liner does not affect biochemical composition of the tobacco leaf, which means that both types of packing can be used without unwanted changes in the product.
- ✓ We can assume that ageing in C-48 carton with Kraft paper liner can go faster because of more opened conditions of storage (air goes through “tobacco cake” easier), whereas in carton with Polyliner conditions are more stable and not affected by weather or season of the year.

According to conclusions, the following can be recommended:

- ✓ For faster ageing in stable weather conditions, Kraft paper can be used. I would recommend this type of storage for domestic use of tobacco.
- ✓ Polyliner is better for maintaining stable conditions of the product during ageing, as well as during the transportation. Storage and ageing in C-48 carton with Polyliner can be useful for prevention of a crop “failure”.

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IV. APPENDIX

Fig. 1 Flue-Curing

Fig. 2 Tobacco leaf grading

Fig. 3 GLT processing

Fig. 4 Thresher

Fig. 5 Classifier

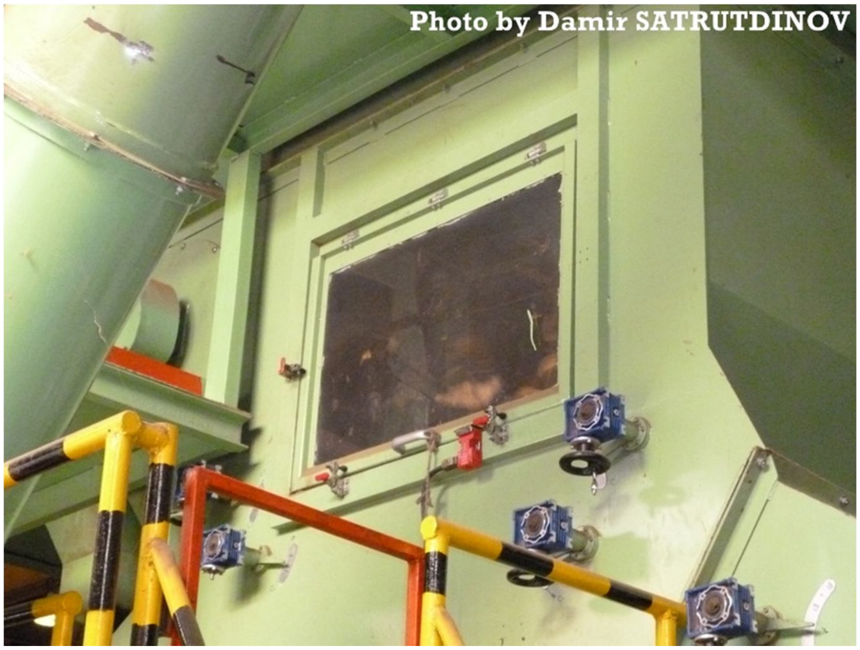

Fig. 6 Lamina press

Fig. 7 Tobacco warehousing

Fig. 8 Tobacco inspection

Fig. 9 Aged tobacco leaf with nicotine spots

Tab. 1 Tobacco production shares in the World, 2000

Country	Production	
	million tons	%
China	2.3	31.1
India	0.6	8.1
Brazil	0.52	7.0
USA	0.4	5.4
EU	0.3	4.1
Rest of the World	3.28	44.3
Overall	7.4	100.0

Tab. 2 Tobacco consumption shares in the World, 2000

Country	Consumption	
	million tons	%
China	2.59	35
India	0.44	6
USA	0.44	6
EU	0.67	9
Rest of the World	3.26	44
Overall	7.4	100

Tab. 3 L*a*b values of the K11 sample

#	L	a	b
1	20.16	8.92	22.42
2	19.17	9.04	19.34
3	22.5	10.45	22.22
4	15.44	8.71	24.75
5	10.18	9.64	45.13
6	16.55	10.12	21.52
7	23.91	11.66	24.68
8	19.61	9.25	24.53
9	54.07	11.01	32.09
10	22.76	10.4	23.53
Avg	22.435	9.92	26.021

Tab. 4 L*a*b values of the P11 sample

#	L	a	b
1	20.01	11.32	20.34
2	35.65	13.52	28.42
3	39.93	13.57	19.55
4	24.25	12.36	16.77
5	21.66	9.86	17.07
6	37.47	14.01	30.68
7	28.14	11.4	26.17
8	52.86	13.27	33.79
9	35.23	9.15	26.81
10	35.55	16	24.09
Avg	33.075	12.446	24.369

Tab. 5 L*a*b values of the K12 sample

#	L	a	b
1	25.89	9.16	25.81
2	29.93	15.51	27.16
3	33.14	12.05	25.8
4	26.3	10.59	27.98
5	34.94	10.64	29.4
6	30.9	12.5	34.31
7	37.16	13.75	28.43
8	34.46	13.39	21.03
9	41.85	14.77	33.9
10	34.66	13.76	27.41
Avg	32.923	12.612	28.123

Tab. 6 L*a*b values of the P12 sample

#	L	a	b
1	48.28	10.63	30.23
2	36.63	8.99	28.83
3	41.48	10.87	30.51
4	49.85	11.36	34.68
5	46.99	10.83	31.1
6	37.95	10.15	29.3
7	41.47	12.73	29.77
8	58.52	10.99	37.05
9	33.39	15.93	29.2
10	69.72	9.11	34.29
Avg	46.428	11.159	31.496

Tab. 7 Exports of Indian tobacco and tobacco products

Period	Tobacco, US$	Tobacco products, US$	Total, US$
2010-2011	700.54	223.4	923.94
2009-2010	770.88	157.49	928.37
2008-2009	591	147.06	738.06
2007-2008	367.42	135.25	502.67
2006-2007	274.75	106.79	381.54
2005-2006	234.43	88.06	322.49
2004-2005	217.49	88.28	305.77
2003-2004	176.27	74.77	251.04
2002-2003	158.18	66.77	224.95
2001-2002	128.27	60.77	189.04