Physical Properties of Non-Fermented and Fermented Tobacco of Burley Varieties and Lines

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Abstract— *The physical properties of the raw material are an objective indicator of the quality of the tobacco leaves and a reflection of their structure. They are very closely related to the structure and the content of the organic matter in the leaf. The selection of the variety, the applied agricultural techniques, the environmental conditions during the vegetation period, the leaf position, the technological maturity, as well as the conditions during drying, are important factors that have a strong impact on the formation of the physical and technological properties of the tobacco raw material. The tests included 4 varieties and 2 lines, namely: L-8 (control variety, Zimbabwe), Kentucky-22 (USA), B-963 (Bulgaria) and B-1246 (Bulgaria), all in fertile form, as well as the male sterile hybrid lines B-204/15 CMS F_1 and B-206 A/15 CMS F_1. The test was planted in 4 repetitions with a planting density of 90×50 cm according to the Randomized Block System method. After the evaluation of the tobacco according to the current Rulebook for qualitative evaluation of raw tobacco, we separated tobacco material from the middle belt, in order to get an insight into the differences of the physical properties from the examined varieties and lines in the non-fermented and fermented tobacco. The percentage portion of the main (mid) rib, the thickness of the leaves, and the materiality of the leaves, are important physical indicators of the quality of the raw material, and from the obtained results we can point out the line B-206 A/15 CMS F_1, where the average content of the main rib of the non-fermented tobacco leaf is within the limits of 26.82%, in the line B-206 A/15 CMS F_1 there is up to 25.13% portion of the main rib of the fermented leafs. The leaf portion in the newly obtained line is within the range from 73.18% (non-fermented tobacco leaf) to 74.87% (fermented tobacco leaf). The materiality is within the range from 41.26 g/m² for non-fermented tobacco leaf up to 41.90 g/m² for fermented tobacco leaf, and the leaf thickness is 91.5 μm (non-fermented tobacco leaf) up to 77.2 μm (fermented tobacco leaf).*

The obtained data from non-fermented and fermented tobacco, the content of the main rib (%), the thickness of the tobacco leaves (μm), the materiality of the leaves (g/cm^2), are determined according to recognized methods that are being applied in the operation of the accredited laboratory - L04 within the Department of Technology, Fermentation and Fabrication at the Scientific Tobacco Institute Prilep.

Keywords— non-fermented, fermented, tobacco, burley, leaves.

I. INTRODUCTION

The raw material of the burley type within the composition of the blend cigarettes participates with approximately 30%. In addition to oriental tobacco varieties in North Macedonia, few years ago large-leaf tobacco varieties were grown, there are favorable conditions for these varieties, and therefore we hope that they will be a part of the tobacco production again. The introduction of the burley type in the typical structure of our country was made by Rudolf Gornik. The author (1985) notes that this tobacco type can be successfully grown only on rich soils in and humid climates with frequent rainfall. In the early seventies, this type of tobacco was the point of departure in the search for a variety that will prove to be the best according to most properties (primarily yield and quality). The burley type is dried in the shade in a closed space, it is an integral part of the blend cigarette mixture, and it is used both for a pipe and as a chewing tobacco. The typical characteristic of burley is a leaf with a spongy tissue and a great ability to absorb liquid substances. The content of nicotine and proteins is high, and as a

result of the long drying process, it contains a low amount of sugar, in traces. Its taste is sharp (ammonia-like), it is used for making American blend cigarettes, whereby it participates with approximately 30% in this mixture (Stankovic, 2002, Georgiev, 2002, Radojčić, 2011). The Ministry of Agriculture, Forestry and Water Economy has recognized several burley male sterile varieties of the Scientific Tobacco Institute - Prilep, including: B-96/85 CMS F_1, Burley 1 CMS F_1, B-2/93 CMS F_1 and Pelagonec CMS F_1, all of which are different and have their own specifics. These varieties meet the physical, technological, degustatory and chemical characteristics that are typical of the burley type. Continuously throughout the operation of the Scientific Tobacco Institute Prilep, because there is no ideal variety that is created once and for all, but there is a variety that at one point is better than the others, the Department of Genetics, Selection and Seed Control in the Scientific Tobacco Institute Prilep still continues to create new varieties, as well as many new hybrid lines, including B-204/15 CMS F_1 and B-206 A/15 CMS F_1 which we analyze in the test. This primarily refers to varieties (genotypes) that will provide higher yields, quality and appropriate technological, chemical and degustatory properties. According to Uzunoski (1985), the physical and technological properties of the raw material are an integral part of the quality of the raw material and together with the chemical and degustatory properties they make a natural connection that the quality of the tobacco leaf depends on.

During the tobacco fermentation, oxidation-reduction reactions occur, as well as reactions of hydrolytic decomposition and condensation of specific chemical compounds. These entire reactions make up the complete fermentation process, indicates Boceski (2003). The chemical composition of tobacco changes, through the regrouping of molecules and the decomposition of compounds into end products, which are separated from the tobacco substrate in the air and in the environment. In this way, not only that the quality of tobacco changes, but tobacco also loses weight. This weight loss is caused by compounds that are separated from the organic matter and a part of the hygroscopic water. This loss is a general loss, while the loss of the tobacco's organic mass is a loss of dry mass or fermentation sludge. Some physical changes that occur after fermentation will be seen in the following presentation.

II. MATERIALS AND METHODS

The test was performed within the premises of the Scientific Tobacco Institute Prilep on alluvial-colluvial soil type that was previously prepared and fertilized with 300 kg/ha within the ratio of nitrogen, phosphorus and potassium - NPK 8:22:20. The tests included 4 varieties and 2 lines - creations of the Scientific Tobacco Institute Prilep, as follows: L-8 (control variety, Zimbabwe), Kentucky-22 (USA), B-963 and B-1246 (Bulgaria), all in fertile form, as well as the male-sterile hybrid lines B-204/15 CMS F_1 and B-206 A/15 CMS F_1. The tobacco was planted in 4 repetitions with a planting density of 90×50 cm on June 6, 2018. During the vegetation, the tobacco was dug twice, and nourished with nutrients once with 3-4 g/stalk of 26% CAN (calcium ammonium nitrate). Due to the frequent rainfall, which was sufficient and properly distributed, there was no additional irrigation. During the vegetation of the plant, the same agro-technical measures were applied for all examined tobacco varieties and lines. The harvesting of the tobacco was performed manually, and the drying was performed in special dryers in shade, typical of the burley type. The dry tobacco was estimated according to the applicable Rulebook, and the physical properties: leaf length and width (cm), main rib content (%), tobacco leaf thickness (μm), materiality of the leaves (g/m2), were determined according to recognized methods used by the accredited laboratory - Laboratory-L04 within the Department of Technology, Fermentation and Fabrication at the Scientific Tobacco Institute Prilep (Smokvoski, 2004).

These properties are one of the most significant ones for the cigarette factories because they directly affect the financial effect achieved through the total number of manufactured smoking units of a specific amount of fine-cut tobacco. According to Uzunoski (1985), the technological properties of the raw material are an integral part of the quality of the raw material and together with the chemical and degustatory properties they form a natural connection that the quality of the tobacco leaf depends on.

III. RESULTS AND DISCUSSION

3.1 Main (mid) rib content (%)

The main rib of the tobacco leaf, in addition to its role of a main conducting system for nutrients, has developed into an organ that also has a skeletal function. As a result of the fact that large-leaf tobacco types, one of which is the burley type, have leaves with large dimensions, the percentage portion of the main rib is also higher.

The lateral nervation of the leaf is poorly developed and does not affect the technological processes of the cigarette factories, while the content of the main rib is a very important factor for the manufacturers and processors of large-leaf tobacco varieties. The percentage portion of the main rib in the process of processing directly affects the profitability of the company.

Table 1 and Figure 1 contain data on the portion of the main rib in non-fermented and fermented tobacco of the varieties and newly obtained hybrid lines.

The lowest percentage of the main rib in the examined varieties and lines of non-fermented tobacco, of 26.82%, was found in the line B-206 A/15 CMS F_1, and up to 32.76% in the variety Kentucky-22 which indicates 17.84% higher relative difference than the control variety (L-8). The other varieties and lines of non-fermented tobacco have a portion of 28.20% of the main rib in the line B-204/15 CMS F_1, up to 32.20% in the variety B-963. After the fermentation in all varieties and lines in the test, we observe a lower percentage of the main rib portion, which is a positive indicator in the further processing of the tobacco leaves. The lowest percentage of the main rib portion of the fermented leaves was found in the line B-206 A/15 CMS F_1 (25.13%), whose index compared to its own control of non-fermented leaves is 93.70%. Furthermore, the highest main rib portion of the fermented leaves was found in the variety Kentucky-22 (30.29%), whose index is 92.46%. From the obtained data compared to the own controls of non-fermented leaves, we notice that during the fermentation of the leaves there has been a decrease in the percentage of the main rib portion in all examined varieties and lines.

Hristoski (2013) indicates that the average content of the main rib in the examined varieties by insertions is within the range from 26.82% in insertion X of the control variety, up to 32.16% in insertion B of the variety B-2/93.

Pelivanoska (1999) points out that intensive agricultural techniques increase the percentage content of the main rib by approximately 6% on average compared to the control variety (extensive agricultural techniques).

Risteski (2008), from the three-year research (1999/2001) in six varieties of the burley type (3 domestic and 3 foreign) cultivated in the region of Prilep, in the variant harvested-cured and stalk-cut harvest, came to the conclusion that the content of the main rib is within the range from 27.46% (stalk-cut) in the Chulenec variety up to 32.62% (harvested-cured) in the C-104 variety. Risteski (2006), in his three-year research came to the conclusion that the average content of the main nerve in both variants of harvesting, is within the range from 27.46% to 32.62%. According to Pezović, et. al. (1983), the main rib content of the mid-belt insertions, depending on the production micro-region, is within the range from 19.98% up to 27.78%.

All tested varieties and lines of fermented tobacco show a lower index (non-fermented: fermented leaves). Or the variety B-963 (80.75%) has the lowest index compared to its own control, and the line B-204/15 CMS F_1 (98.94%) has the highest index.

TABLE 1
PORTION OF THE MAIN (MID) RIB OF FERMENTED AND NON-FERMENTED TOBACCO (%)

Variety	Rib Portion in non-fermented tobacco in %	Relative	Rank	Rib Portion in fermented tobacco in %	Relative	Rank	Index	Rank
L-8 Zimbabwe	27.80	100.00	5	26.43	100.00	5	95.07	5
Kentucky-22 USA	32.76	117.84	1	30.29	114.60	1	92.46	3
B-963 Bulgaria	32.20	115.82	2	26.00	98.37	2	80.75	1
B-1246 Bulgaria	28.83	103.71	3	26.56	100.49	4	92.13	2
B-204/15 CMS F_1	28.20	101.44	4	27.90	105.56	3	98.94	6
B-206 A/15 CMS F_1	26.82	96.47	6	25.13	95.08	6	93.70	4

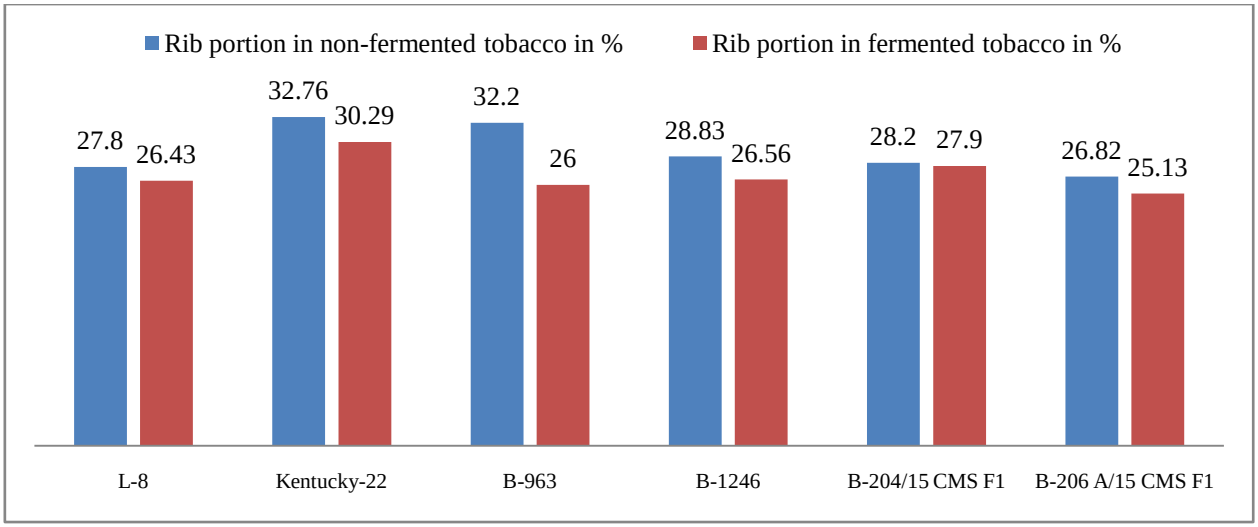

FIGURE 1: Main Rib portion of non-fermented and fermented tobacco in %

According to Uzunoski (1985), in regard to the leaves of the burley type, the share of the main nerve in the total mass of the leaf participates with approximately 30%.

The content of the main rib in the examined varieties is correlated with the cited literary data, and it is within the expectations. We also found that fermented tobacco compared to non-fermented tobacco participates with a lower percentage of the main rib, which depends on the examined variety and line.

3.2 Leaf portion of non-fermented and fermented tobacco (%)

The percentage portion of the leaves compared to the percentage portion of the main rib is inversely proportional, whereby the percentage portion of the leaves is lower in non-fermented tobacco, compared to the fermented leaves where the percentage portion is higher. According to Table 2 and Figure 2, the highest leaf portion of the non-fermented tobacco was found in the line B-206 A/15 CMS $_{F1}$ (73.18%), and the lowest percentage was found in the variety Kentucky-22 (67.24%). In the fermented tobacco, the highest percentage portion of the leaf was again found in the line B-206 A/15 CMS F_1 (74.87%), and the lowest percentage portion was found in the variety Kentucky-22 (69.71%). According to the obtained data, all examined varieties and lines of fermented tobacco show a higher index (non-fermented: fermented leaves). More specifically, the variety L-8 has the lowest index (101.90%) compared to its own control variety, and the variety B-963 has the highest index (148.34%). The leaf portion in all examined varieties and lines in fermented tobacco is higher as a result of the reduced percentage share of the main rib, whose index in B-206 A/15 CMS F_1 is 139.07%, in B-204/15 CMS F1 it is 136.49%, in B-1246 it is 140.26%, and in Kentucky-22 it is 140.91%.

TABLE 2
LEAF PORTION OF NON-FERMENTED AND FERMENTED TOBACCO (%)

Variety	Leaf Portion in non-fermented tobacco in %	Relative	Rank	Leaf Portion in fermented tobacco in %	Relative	Rank	Index	Rank
L-8 Zimbabwe	72.20	100.00	2	73.57	100.00	3	101.90	6
Kentucky-22 USA	67.24	93.13	6	69.71	94.75	6	140.91	2
B-963 Bulgaria	67.80	93.91	5	74.00	100.58	2	148.34	1
B-1246 Bulgaria	71.17	98.57	4	73.44	99.82	4	140.26	3
B-204/15 CMS F_1	71.80	99.45	3	72.10	98.00	5	136.49	5
B-206 A/15 CMS F_1	73.18	101.36	1	74.87	101.77	1	139.07	4

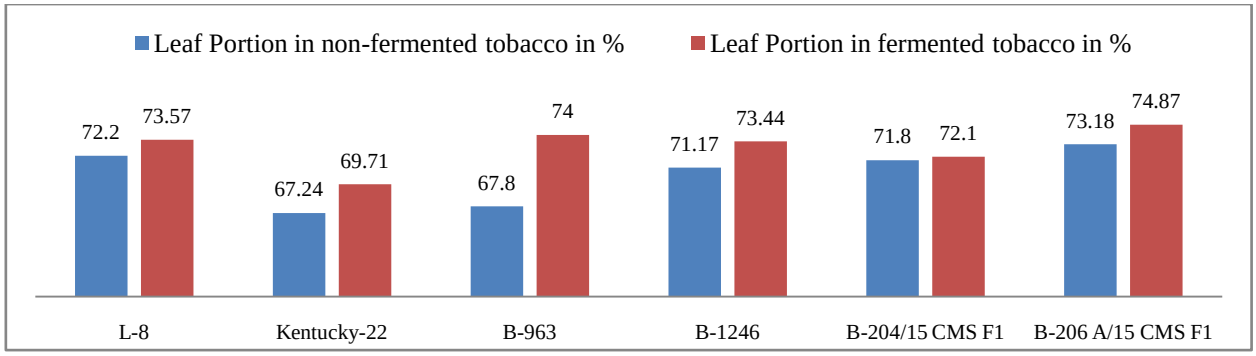

FIGURE 2: Leaf portion of fermented and non-fermented tobacco in %

3.3 Leaf materiality (g/m²)

The materiality or content of the leaf tissue is also one of the important physical properties of the raw material that determine the quality of the leaves. Tobacco leaves that are characterized by roughness, thick or empty leaf tissue, i.e. their materiality is very high or very low, have lower quality i.e. this is a negative indicator of the tobacco quality.

The thinner and more elastic the leaf tissue, the higher the quality. Usually the leaves of the upper belt are slightly thicker and rougher, with a denser cell structure and therefore their materiality is higher. In our tests, leaves from the middle belt were taken. In Table 3 and Graph 3 the materiality of the leaves of non-fermented tobacco is within the range from 35.50 g/m^2 in the variety B-963, up to 57.08 g/m2 in the line B-204/15 CMS F_1. The newly obtained line B-206 A/15 CMS F_1 is characterized by lower materiality (41.26 g/m2) compared to other varieties, which is a positive indicator of the quality of the tobacco raw material. After the fermentation of the tobacco leaves, the materiality is within the range from 53.29 g/m2 in the control variety L-8, up to 38.58 g/m2 in the variety B-963. From the tests we can reach the conclusion that there is no significant change after the tobacco fermentation, and depending on the variety and the line, the index either increases or decreases by some percentage, and the index (for non-fermented: fermented tobacco leaf) is within the range from 93.17% in the line B- 204/15 CMS F_1, up to 108.68 in the variety B-963.

Hristoski (2013) indicates the insertion X in the burley tobacco with an origin from India is characterized by the lowest materiality (33.14 g/m2), and the insertion T with an origin from Greece i.e. Sri Lanka is characterized by the highest materiality (43.70 g/m^2 and 43.44 g/m^2). Pelivanoska (1999) presents data according to which the materiality of the leaves of the burley variety grown in (1996/1998) in conditions of different intensity of agricultural techniques, is within the range from 34.75 g/m² (fertilized and irrigated with 70% of the field water capacity - PWC) up to 52.26 g/m² (fertilized and non-irrigated).

From the studies (1999/2001) conducted with six male sterile varieties of the burley type, Risteski (2008) came to the conclusion that the average materiality of the leaves is within the range from 38.72 g/m2 (stalk-cut harvest) in the control variety up to 42.95 g/m2 (harvested-cured) in the burley-1 variety.

TABLE 3
MATERIALITY OF FERMENTED AND NON-FERMENTED TOBACCO (g/m²)

Variety	Materiality of the leaf in non-fermented tobacco in g/m^2	Relative	Rank	Materiality of the leaf in fermented tobacco in g/m^2	Relative	Rank	Index	Rank
L-8 Zimbabwe	56.20	100.00	2	53.29	100.00	1	94.82	5
Kentucky-22 USA	47.96	85.34	3	50.30	94.39	3	104.88	2
B-963 Bulgaria	35.50	63.17	6	38.58	72.40	6	108.68	1
B-1246 Bulgaria	44.65	79.45	4	45.07	84.57	4	100.94	4
B-204/15 CMS F_1	57.08	101.57	1	53.18	99.79	2	93.17	6
B-206 A/15 CMS F_1	41.26	73.42	5	41.90	78.63	5	101.55	3

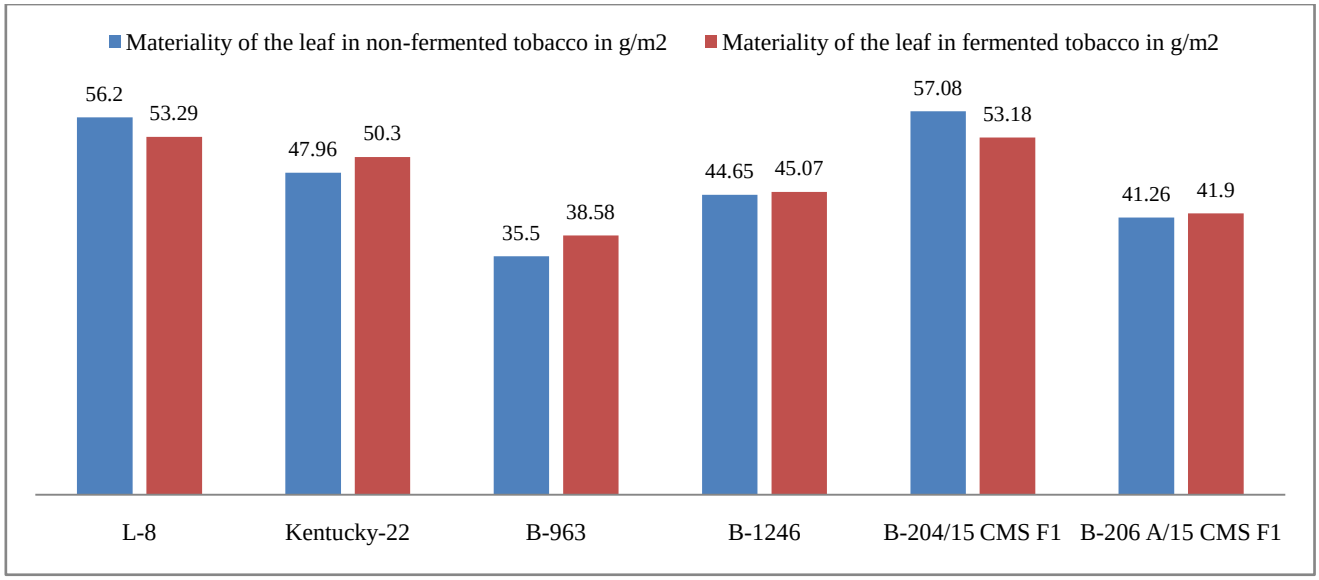

FIGURE 3: Materiality of fermented and non-fermented tobacco in g/m^2

3.4 Thickness of the tobacco leaves (µm)

The thickness of the leaf tissue is a reflection of the quality of the raw material. One should bear in mind that in burley tobacco varieties, specifically the lower insertions are characterized by thin leaf tissue. By reducing the thickness of the leaf, the quality of the raw material increases, with the exception of the leaves that are not sufficiently ripe or have become overripe in the course of the vegetation period, or more precisely, empty no-content tobacco. According to Tomič et al. (1977), the thickness of the tobacco leaf varies from 50 to 150 µm. The authors point out that the leaf is thin when the average thickness of the leaf tissue is 70 µm, an average thickness is when the leaf tissue has 70-100 µm and a thick leaf tissue is the one that exceeds 100 µm (micrometers).

The thickness of the leaves depends on the variety, the soil-climatic conditions, the applied agricultural techniques during the vegetation period, the mineral nutrition, the irrigation and the period when the tobacco leaf was harvested.

From the results presented in Table 4 and Figure 4, it is observable that the average leaf tissue thickness in almost all examined varieties and lines is typical for the burley tobacco type, whose tobacco raw material belongs to medium-thick leaves.

TABLE 4
THICKNESS OF NON-FERMENTED AND FERMENTED TOBACCO (µm)

Variety	Leaf thickness in non-fermented tobacco in µm	Relative	Rank	Leaf thickness in fermented tobacco in µm	Relative	Rank	Index	Rank
L-8 Zimbabwe	89.3	100.00	5	78.6	100.00	2	88.02	2
Kentucky-22 USA	95.9	107.39	3	77.3	98.35	4	80.60	5
B-963 Bulgaria	78.3	87.68	6	76.0	96.69	6	97.06	1
B-1246 Bulgaria	102.6	114.89	1	82.5	104.96	1	80.41	6
B-204/15 CMS F_1	96.3	107.84	2	77.9	99.11	3	80.89	4
B-206 A/15 CMS F_1	91.5	102.46	4	77.2	98.22	5	84.37	3

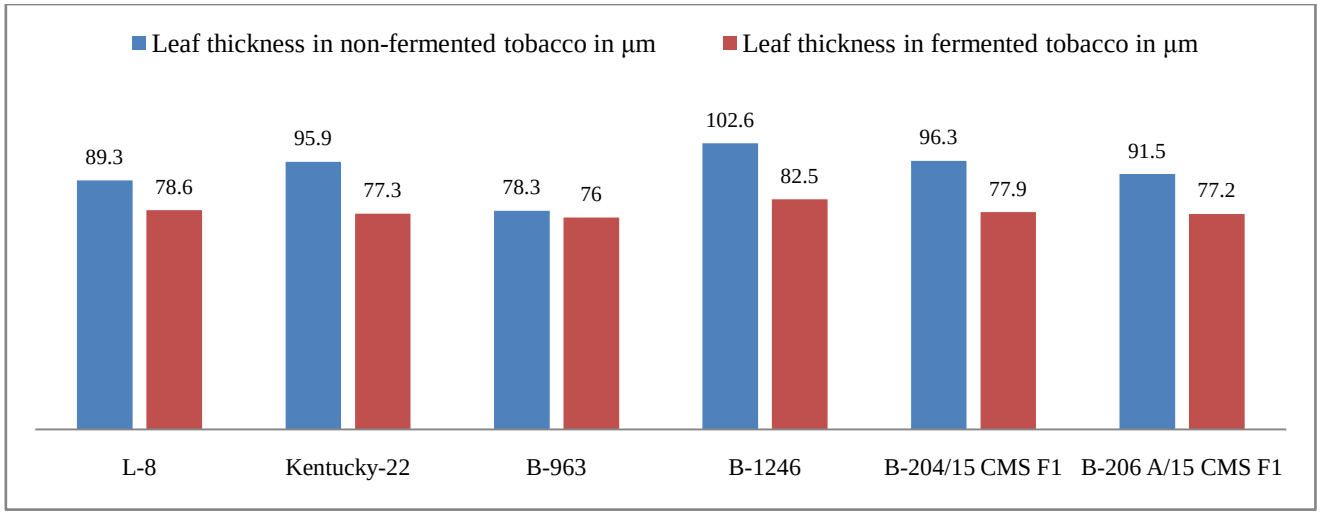

FIGURE 4: Leaf thickness of non-fermented and fermented tobacco in µm

The leaf thickness of non-fermented tobacco of the variety B-1246 (102.6 µm) has the highest value, while the lowest thickness is found in the variety B-963 (78.3 µm). After fermentation, the leaf thickness in all examined varieties and lines decreases, ranging from 82.5 µm in the variety B-1246, up to 77.2 µm in the line B-206 A/15 CMS F_1. The index percentage is lower than the own control in all examined varieties and lines compared (non-fermented: fermented tobacco leaf), it is within the range from 97.06 µm in the variety B-963, to 80.41 µm in the variety B-1246.

Filiposki (1986) concluded that mineral nutrition and irrigation of tobacco have an effect on the reduction of the thickness of the leaf tissue.

Pelivanoska (1999), in her three-year (1996/1998) researches on the impact of agricultural techniques on the quality of the burley raw material, came to the conclusion that the average thickness of the leaf tissue is within the range of 54.00 µm (fertilized and irrigated with 70% of the field water capacity - PWC up to 67.16 µm (control). Risteski (2006), from the researches (1999/2001) in six varieties of the burley type grown in the Prilep region, came to the conclusion that the average thickness of the leaf tissue is within the range of 61.00 µm (harvested-cured) in the variety C-104 up to 71.83 µm (stalk-cut harvest) in the control variety, B-96/85.

The data regarding the thickness of the leaf tissue in the examined varieties from the test are in accordance with the cited literary data, that is, they are within the expectations and are typical of the burley type. The thickness of the leaf tissue is a varietal characteristic and depends on the influence of the soil-climate factors, the applied agro-technique as well as the manner and technology of drying.

IV. CONCLUSION

Based on the obtained results, the following conclusions can be drawn:

- The line B-206 A/15 CMS F1 is characterized by the lowest percentage portion of the main rib in the examined varieties and lines, where the portion of the main rib in the non-fermented tobacco leaf is 26.82%, and in the fermented one it is 25.13%. The highest percentage of the main rib is of the variety Kentucky-22 in non-fermented tobacco (32.76%) and fermented tobacco (30.29%).
- The leaf percentage portion is highest in the non-fermented tobacco from line B-206 A/15 CMS F_1 (73.18%) and the fermented tobacco (74.87%). The Kentucky-22 variety has the lowest percentage of leaves, the non-fermented has 67.24%, and the fermented tobacco has 69.71% leaves.
- The leaf materiality of the non-fermented tobacco is within the range from 35.50 g/m^2 in the variety B-963, up to 57.08 g/m^2 in the line B-204/15 CMS F_1. The newly obtained line B-206 A/15 CMS F_1 is characterized by lower materiality (41.26 g/m2) compared to the other varieties, which is a positive indicator of the quality of the tobacco raw material. After the fermentation of the tobacco leaves, the materiality is within the range from 53.29 g/m2 in the control variety L-8, up to 38.58 g/m2 in the variety B-963.

- The leaf thickness is highest in the non-fermented tobacco of the variety B-1246 (102.6 μm) and it is 82.5 μm in the fermented tobacco of the same variety compared to other varieties and lines. The lowest leaf thickness is found in the variety B-963 (78.3 μm) in the non-fermented tobacco, and 76.0 μm in the fermented tobacco leaves.

From the tests we can conclude that the newly obtained line B-206 A/15 CMS F_1 has typical physical properties for the burley type.

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