Mechanical properties of crepe paper and chickpaper

Mechanické vlastnosti krepového a "chickpaper" papierov

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Abstract

The paper deals with the evaluation of the mechanical properties of the crepe paper and chickpaper. The thickness of crepe paper was 300 μm with the surface mass 150 $g*m^{-2}$ and chickpaper paper thickness was 100 μm with the surface mass 40 $g*m^{-2}$. Crepe paper and chickpaper are usually used for chicken breeding. Longitudinal and transversal tensile properties were studied. The tensile behavior was monitored on the motorized test stand ANDILOG STENTOR 1000 (Andilog Technologies, Vitrolles, France).There were measured the tensile properties as modulus of elasticity, maximal elongation, maximal tensile force, tensile strengths, tensile index and strain at break of the longitudinal and transversal samples by testing paper strips. Mean values of the maximal elongation δ_b of longitudinal chickpaper samples were three times smaller than maximal elongation of transversal samples. Mean values of maximal tensile force F_t, tensile strength σ^b_T , tensile index σ^w_T and maximal strain at break ε_T of longitudinal chickpaper samples were two times smaller than maximal quantities of transversal samples. Mean values of the tensile modulus of elasticity of longitudinal and transversal chickpaper samples were almost equal. Chickpaper mechanical properties in tension were different in the longitudinal and transversal direction of the original paper surface. Mean values of the maximal elongation δ_b and maximal strain at break ε_T of longitudinal crepe paper samples were sixty times smaller than maximal elongation and maximal strain at break of transversal samples. Mean values of maximal tensile force F_t, tensile strength σ^b_T and tensile index σ^w_T of longitudinal crepe paper samples were fourth times smaller than maximal quantities of transversal samples. Mean values of the tensile modulus of elasticity of longitudinal samples of crepe paper were thirty eight times smaller than values of transversal samples.

Keywords: chickpaper, crepe paper, tensile properties

Abstrakt

Práca sa zaoberá hodnotením mechanických vlastností, krepového a chickpaper papierov. Hrúbka krepového papiera bola 300 μm s plošnou hmotnosťou 150 g*m^{-2} a chickpaper papiera 100 μm s plošnou hmotnosťou 40 g*m^{-2}. Boli študované ťahové vlastnosti papierov pri zaťažení v pozdĺžnom a priečnom smere. Ťahové správanie papierov bolo testované na zariadení ANDILOG STENTOR 1000 (Andilog Technologies, Vitrolles, France).Boli merané ťahové vlastnosti ako sú: modul pružnosti, maximálne predĺženie, maximálne ťahová sila, tržné zaťaženie, index pretrhnutia a ťažnosť pri pretrhnutí pre pozdĺžne a priečne vzorky testovaním papierových prúžkov. Stredné hodnoty maximálneho predĺženia δ_b pozdĺžnych chickpaper vzoriek boli trikrát menšie než maximálne predĺženia priečnych vzoriek. Stredné hodnoty maximálnej ťahovej sily F_t, tržného zaťaženia σ^b_T , indexu pretrhnutia σ^w_T a maximálna deformácie pri pretrhnutí ε_T pozdĺžnych chickpaper vzoriek boli dvakrát menšie než maximálne hodnoty priečnych vzoriek. Stredné hodnoty modulu pružnosti v ťahu pre pozdĺžne i priečne vzorky boli rovnaké. Mechanické vlastnosti chickpaper papiera v ťahu boli odlišné pri porovnaní v pozdĺžnom a priečnom smere namáhania vzoriek. Stredné hodnoty maximálneho predĺženia δ_b a maximálnej deformácie pri pretrhnutí ε_T pre pozdĺžne vzorky krepového papiera boli šesťdesiatkrát menšie než maximálne predĺženia a maximálne deformácie pre priečne vzorky. Stredné hodnoty maximálnej ťahovej sily F_t, tržného zaťaženia σ^b_T a indexu pretrhnutia σ^w_T pozdĺžnych vzoriek krepového papiera boli štyrikrát menšie než maximálne hodnoty priečnych vzoriek. Stredné hodnoty modulov pružnosti v ťahu pre pozdĺžne vzorky krepového papiera boli tridsaťosemkrát menšie než hodnoty pre priečne vzorky. Mechanické vlastnosti krepového papiera v ťahu boli veľmi odlišné v pozdĺžnom a priečnom smere pri zaťažení vzhľadom na povrch papiera.

Kľúčové slová: chickpaper, krepový papier, ťahové vlastnosti

Detailný abstrakt

Práca sa zaoberá hodnotením mechanických vlastností, krepového a chickpaper papierov. Hrúbka krepového papiera bola 300 μm s plošnou hmotnosťou 150 g*m^{-2} a chickpaper papiera 100 μm s plošnou hmotnosťou 40 g*m^{-2}. Boli študované ťahové vlastnosti papierov pri zaťažení v pozdĺžnom a priečnom smere. Ťahové správanie papierov bolo testované na zariadení ANDILOG STENTOR 1000 (Andilog Technologies, Vitrolles, France).Boli merané ťahové vlastnosti ako sú: modul pružnosti, maximálne predĺženie, maximálne ťahová sila, tržné zaťaženie, index pretrhnutia a ťažnosť pri pretrhnutí pre pozdĺžne a priečne vzorky testovaním papierových prúžkov. Chickpaper je špeciálne vyrobený papier určený na odchov kurčiat. Prvé dni v živote kurčiat sú rozhodujúce. Len pokiaľ mladé kuriatko dokáže rýchlo prijať dostatok vody a potravy, bude rastový vzorec v nasledujúcich týždňoch

úspešný. Vysoko kvalitný Chickpaper je v tomto procese nenahraditeľný. Znižuje prvotýždňovú úmrtnosť, zabezpečuje vyššiu priemernú hmotnosť. Pracuje sa s ním jednoducho. Papier je vyrolovaný v halách pod napájačkami a pod kŕmitkami. Jeho úlohou je vlastne navigovať jednodňové kurčatá k potrave. Pohybom kurčiat po papieri vzniká zvuk, ktorý priláka ostatné a podporuje aj hrabavý reflex Týmto spôsobom taktiež nájdu potravu i vodu. Faktom je, že papier rýchlo absorbuje kvapky vody a robí prostredie pre kuriatka hygienickejším. Je 100% rozložiteľný a je s ním ľahká manipulácia, nakoľko je balený v kotúčoch v šírke 68 cm. Je zabezpečené hygienické balenie vo fólii, ktoré zároveň ochraňuje produkt aj proti vlhkosti pri jeho skladovaní. Má zdrsnený povrch, ktorým sa predchádza poškodeniu pazúrov. Je vyrábaný a dodávaný na trh v troch kvalitách podľa doby rozložiteľnosti papiera. V práci sme sa zaoberali skúmaním vlastností Intra Chickpaper - s návinom 220 m v rolke, s rozložiteľnosťou 2 - 3 dni, baleným po 2 ks. Krepovanie papiera je mechanická úprava, pri ktorej sa papier skladá do jemných záhybov. Dáva tým papieru poddajnosť a mäkkosť, mení jeho mechanické vlastnosti, ako napr. pevnosť v ťahu, ťažnosť a iné. Papier technický krep je vyrábaný skrepovaním sulfátového papiera na krepovacom stroji. Ako surovina sa požíva baliaci papier, produkty Unikraft Plus, Unikraft Beta a Unikraft Gamma pre nebielený technický krep. Krepový papier je vyrábaný v prírodnom odtieni, povolené sú aj farebné odtiene. Papier musí byť po celej ploche rovnomerne skrepovaný.

Introduction

Mechanical properties of the chickpaper and the crepe papers are important for the possibilities to evaluate of suitable conditions for chicken breeding. The objective of this study was to examine the tensile behaviour and the tensile properties of chickpaper and crepe paper as modulus of elasticity, maximal elongations, maximal tensile forces, tensile strengths, tensile indexes and strain at breaks of the longitudinal and transversal samples by testing paper strips.

Gurav et al. (2003) interested with the tensile tests based on ISO 1924-2. The specimen used for testing had dimension (15x70) mm. The rate of elongation was set to 5 mm*min^{-1}. The maximum value of stress as a function of crack position was measured.

Khantayanuwong (2002) described a decrease in the tensile strength of recycled handsheets which was caused by the decrease of interfiber bonding strength as explainable by using the Page equation. Because the recycling treatment did not affect the specific strength of interfiber bonding, the decreased strength of interfiber bonding solely stemmed from the decreased interfiber-bonded area.

Nazhad et al. (2000) studied two softwoods mechanical pulps from species of differing fibre length and coarseness which were fractionated by fibre length and formed into handsheets at standard handsheet consistency and at a headbox consistency. The objective of his study was to determine the effects of multi-stage straining during wet pressing and drying on the tensile properties of dried paper.

Kouko et al. (2014) studied an influence of straining during wet pressing and drying on strength properties of paper. The results showed that increased straining generally led, almost linearly, to decreased strain at break of the dried paper. Tensile stiffness was increased considerably (i.e. 15-20%) by straining at the press section and during drying.

Haslach (2000) interesting in question is whether the time-dependent properties are a consequence of the fiber micro-structure, the interfiber bond, the fiber distribution in a sheet, or a combination of these. Hypotheses for the physical mechanisms responsible for stress-strain relations observed under constant, monotonic, and cyclic loading and, especially, for the role of moisture bonding in the time-dependent behavior are compared. Classical tensile tests on wet papers and rheology measurements on immersed thick papers have been performed.

Schröder and Bensarsa (2002) interested in calculation of the Young's modulus E_P and the out-of-plane shear modulus G_P of the wet papers and from the latter. They deduced the out-of plane shear modulus of the wet fibres. A model for paper deformation during in-plane tension was derived, that took into account the out-of-plane shearing of fibres.

Material and Methods

Chickpaper is special – purpose made paper. The paper was made in Intracare BV (2015), (Figure 1.). It is aimed on the chick breeding. The first days in the life of the chicks are critical. Only when the small chick is able to accept quickly the nourishment the growth factor will be successful in the next weeks. The high quality chickpaper is irretrievable in the process. It decreases the first week mortality and provides higher average weight. The working with the paper is simple. Paper is rolling in the halls under of feeding pumps and under the feeders. The assignment of the paper is a navigation of one day old chickens to the feed. The sound is created by the moving of the chickens on the paper. It lures other chickens and also supports gallinaceous reflex. They will also find the feed and the water. Paper quickly absorbs the drops of water and creates the environment more hygienic for the chickens. Paper is totally decomposable. Manipulation is very easy with it. Paper is packed in the rolls of the width 68 cm. Packaging is hygienic and is provided by polyethylene films, which protects the product against the moisture at the storage. Paper has roughened an outer surface, what prevents of damaging of claws. Intra Chickpaper was used in the roll of length of 220 m. Decomposability of paper was 2 – 3 days. Creping of the paper is mechanical modification. Paper is folding to the fine folds. Paper is getting a compliance and softness and the creping changes its mechanical properties, e. g. tensile strengths and tensibility. Used paper was technical crepe, which was made by creping of sulphate paper on creping machine. Products Unicraft Plus, Unicraft Beta and Unicraft Gamma was used as the raw material for production of the crepe paper. Paper has to be uniformly creped throughout all surface. The samples of the crepe and chickpaper papers were studied for the evaluation of the mechanical properties. Longitudinal and transversal tensile properties were studied. The thickness of crepe paper was 300 μm with the surface mass 150 $g*m^{-2}$ and the thickness of chickpaper paper 100 μm with the surface mass 40 $g*m^{-2}$.

Figure 1. Chickpaper (Intracare BV, 2015)

Obrázok 1. Chickpaper papier (Intracare BV, 2015)

Tensile Test

Samples were cut in the longitudinal and transversal direction of the original paper surface on the dimensions (180 × 15) mm. Initial length of samples was 180 mm and initial cross section area of chickpaper samples was 1.55 mm^2 and of crepe samples was 4.64 mm^2. Ten samples of the paper strips were used for each sort. In this test, a load was applied along the longitudinal axis of a test samples. The applied load and the resulting elongation of the member were measured. The process was repeated with increased load until the desired load levels were reached or the specimen breaks. The tensile behaviour was monitored on the motorized test stand Andilog Stentor 1000 (Andilog Technologies, Vitrolles, France). Maximal reached force for chickpaper samples was about 3.5 N for longitudinal samples and about 6.8 N for transversal samples and for crepe paper samples was about 4.8 N for longitudinal loading and about 18.3 N for transversal samples. The force *F* (N) and elongation δ (mm) were measured when the speed of flat grip fixtures was 20 $mm*min^{-1}$ and data were stored in the xls format in the computer by means of analogue to digital converter and software RSIC v 4.06 (Andilog Technologies, Vitrolles, France). The force and elongation were calculated as the tensile stress σ (MPa) and the strain ε ($mm*mm^{-1}$). The tensile stresses σ (MPa) were determined from the equation:

$$\sigma = \frac{F}{S} \qquad (1)$$

where:

F – force (N)

S – initial cross section area of the strips (mm^2)

The strains ε ($mm*mm^{-1}$) were determined as a change in the sample’s gage length from the equation:

$$\varepsilon = \frac{\delta}{l} \qquad (2)$$

where:

δ – elongation (mm)
l – initial length (mm)
Tensile modulus of elasticity *E* (MPa) was defined from the equation:

$$E = \frac{S_{\max} l}{bt} \tag{3}$$

where:

S_{max} – maximal slope of the curve of force versus elongation ($N*mm^{-1}$)
l – initial length of the specimen (mm)
b – initial width of the specimen (mm)
t – thickness of the paper (mm)

Tensile strength σ_T^b ($kN*m^{-1}$) is maximal tensile force referring on the unit of the width, which paper suffers before the breaking. The maximal tensile force of each specimen was determined. The average maximal tensile force was calculated and then the tensile strength was evaluated from the equation:

$$\sigma_T^b = \frac{\overline{F_t}}{b} \tag{4}$$

where:

σ_T^b – tensile strength ($kN*m^{-1}$)
$\overline{F_t}$ – average maximal tensile force (N)
b – initial width of the specimen (mm)

Tensile index σ_T^w ($kNm*kg^{-1}$) was defined from the equation:

$$\sigma_T^w = \frac{1000\ \sigma_T^b}{w} \tag{5}$$

where:

σ_T^w – tensile index ($kNm*kg^{-1}$)
w – surface mass ($g*m^{-2}$)

Maximal strain at break ε_T (%) was defined as the percent of the initial length of the specimen from the equation:

$$\varepsilon_T = \frac{\delta_b}{l} \times 100 \tag{6}$$

where:

δ_b – maximal elongation (mm)
l – initial length (mm)

The maximal elongation was measured at the moment of breaking of the sample (STN EN ISO 1924–2, 2009). The force and elongation were transformed by means of software Microsoft Office Excel 2003 on the tensile stress σ (MPa) and the strain ε ($mm*mm^{-1}$).

Results and Discussion

Typical tensile diagram of paper strip of chickpaper of longitudinal sample 1 from ten realized samples is presented in the Figure. 2. Maximal tensile force F_t was 3.72 N and a maximal elongation δ_b was 5.37 mm. Maximal strain at break ε_T = 2.98% was calculated from the equation (6). The tensile strength σ_T^b = 0.25 $kN*m^{-1}$ was evaluated from the equation (4). Tensile index σ_T^w = 6.20 $kNm*kg^{-1}$ was calculated from the equation (5). Typical determination of maximal slope S_{max} = 1.1687 $N*mm^{-1}$ of longitudinal loading of longitudinal paper strip of chickpaper of sample 1 from ten realized samples is presented in the Figure 3. Slope was determined on the base of linear regression from the linear part of the tensile diagram.

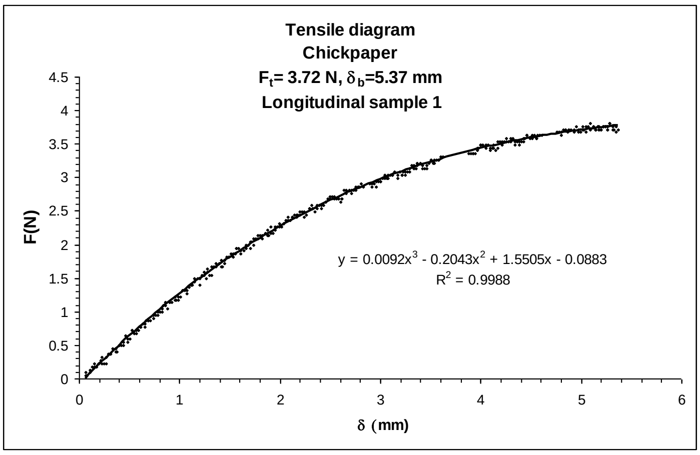

Figure 2. Tensile diagram of chickpaper longitudinal sample no. 1 and values of maximal tensile force F_t = 3.72 N and maximal elongation at break δ_b= 5.37 mm

Obrázok 2. Ťahový diagram pozdĺžnej vzorky chickpaper papiera č. 1 a hodnoty maximálnej ťahovej sily F_t = 3,72 N a maximálneho predĺženia pri pretrhnutí δ_b = 5,37mm

Tensile modulus of elasticity E =135.50 MPa was calculated from the equation (3) on the base of S_{max} value. Results of longitudinal loading of the examined longitudinal chickpaper samples are presented in the Table 1. Typical tensile diagram of paper strip of chickpaper of transversal sample 3 from ten realized samples is presented in the Figure 4. Maximal tensile force F_t was 7.40 N and a maximal elongation δ_b was 14.28 mm. Maximal strain at break ε_T = 7.93% was calculated from the equation (6). The tensile strength σ_T^b = 0.49 $kN*m^{-1}$ was evaluated from the equation (4).

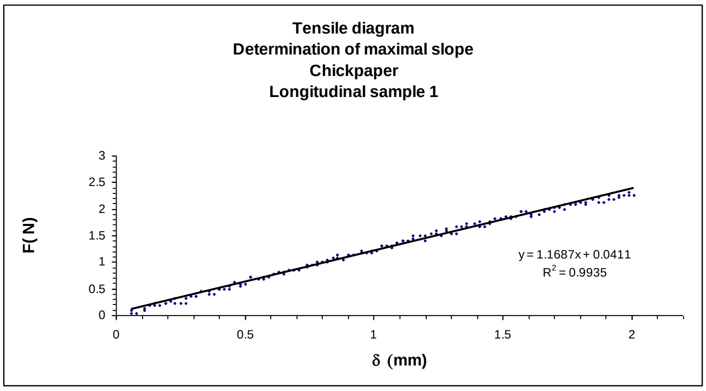

Figure 3. Determination of maximal slope S_{max} = 1.1687 N*mm^{-1}of chickpaper longitudinal sample no. 1

Obrázok 3. Stanovenie maximálnej smernice S_{max} = 1,1687 N*mm^{-1} pozdĺžnej vzorky č. 1 chickpaper papiera

Table 1. Results of the longitudinal loading of longitudinal samples of chickpaper

Tabuľka 1. Výsledky pozdĺžneho zaťaženia pozdĺžnych vzoriek chickpaper papiera

Chickpaper	Longitudinal						
Sample	δ_b (mm)	F_t (N)	σ^b_T (kN∗m^{-1})	σ^w_T (kNm*kg^{-1})	ε_T (%)	S_{max} (N*mm^{-1})	E_L (MPa)
1.	5.37	3.72	0.25	6.20	2.98	1.17	135.50
2.	6.93	4.26	0.28	7.11	3.85	1.29	149.87
3.	3.38	3.32	0.22	5.53	1.88	1.29	149.30
4.	4.04	3.63	0.24	6.05	2.24	1.27	147.50
5.	4.16	3.63	0.24	6.05	2.31	1.31	152.19
6.	3.98	3.45	0.23	5.75	2.21	1.30	151.26
7.	3.54	2.49	0.17	4.16	1.97	1.66	191.98
8.	3.50	3.40	0.23	5.67	1.94	1.52	176.65
9.	4.66	3.86	0.26	6.43	2.59	1.29	149.72
10.	4.49	3.63	0.24	6.05	2.49	1.26	146.34
Mean	4.40	3.54	0.24	5.90	2.45	1.34	155.03
s	0.34	0.14	0.01	0.24	0.19	0.05	5.22
s (%)	7.71	4.05	4.05	4.05	7.71	3.37	3.37

δ_b – maximal elongation, F_t – maximal tensile force, σ^b_T – tensile strength, σ^w_T – tensile index, ε_T – maximal strain at break, S_{max} – maximal slope of the curve of force versus elongation, E_T – tensile modulus of elasticity, s – standard deviation

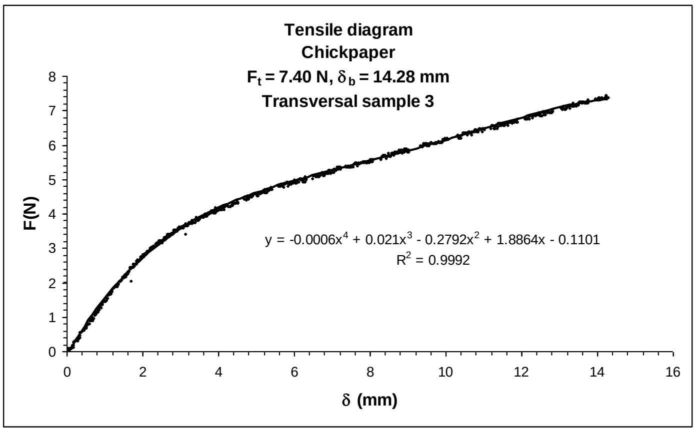

Figure 4. Tensile diagram of chickpaper transversal sample no. 3 and values of maximal tensile force F_t = 7.40 N and maximal elongation at break δ_b= 14.28 mm

Obrázok 4. Ťahový diagram pozdĺžnej vzorky chickpaper papiera č. 3 a hodnoty maximálnej ťahovej sily F_t = 7,40 N a maximálneho predĺženia pri pretrhnutí δ_b = 14,28 mm

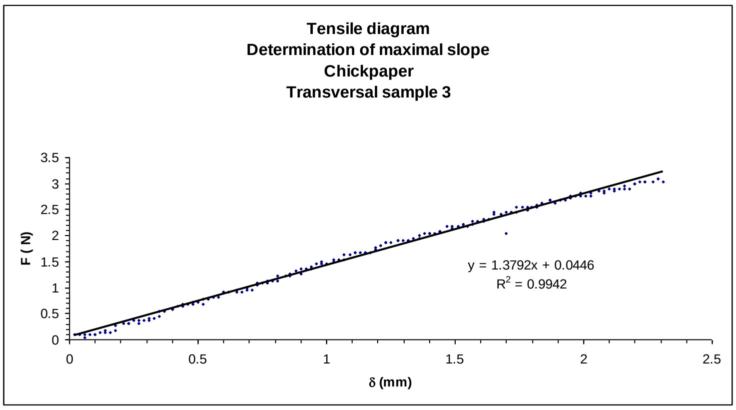

Figure 5. Determination of maximal slope S_{max} = 1.3792 N*mm^{-1}of chickpaper longitudinal sample no. 3

Obrázok 5. Stanovenie maximálnej smernice S_{max} = 1,3792 N*mm^{-1} pozdĺžnej vzorky č. 3 chickpaper papiera

Tensile index σ_T^w = 12.32 kNm*kg^{-1} was calculated from the equation (5). Typical determination of maximal slope S_{max} = 1.3792 N*mm^{-1} of longitudinal loading of transversal paper strip of chickpaper of sample 3 from ten realized samples is presented in the Figure 5. Slope was determined on the base of linear regression from the linear part of the tensile diagram.Tensile modulus of elasticity *E* =159.91 MPa was calculated from the equation (3) on the base of S_{max} value. Results of longitudinal loading of the examined transversal chickpaper samples are presented in the Table 2. Typical tensile diagram of paper strip of crepe paper of longitudinal sample 1 from ten realized samples is presented in the Figure 6. Maximal tensile force F_t was 5.44 N and a maximal elongation δ_b was 1.22 mm. Maximal strain at break ε_T = 0.68% was calculated from the equation (6). The tensile strength σ_T^b = 0.36 kN∗m^{-1} was evaluated from the equation (4). Tensile index σ_T^w = 2.42 kNm*kg^{-1} was calculated from the equation (5).

Table 2. Results of the longitudinal loading of transversal samples of chickpaper

Tabuľka 2. Výsledky pozdĺžneho zaťaženia priečnych vzoriek chickpaper papiera

Chickpaper	Transversal						
Sample	δ_b (mm)	F_t (N)	σ^b_T (kN∗m^{-1})	σ^w_T (kNm*kg^{-1})	ε_T (%)	S_{max} (N*mm^{-1})	E_T (MPa)
1.	12.13	7.80	0.52	13.00	6.52	1.28	148.29
2.	12.61	7.03	0.47	11.72	7.01	1.37	159.06
3.	14.28	7.39	0.49	12.32	7.93	1.38	159.91
4.	13.00	6.53	0.44	10.89	7.22	1.33	154.35
5.	13.94	6.71	0.45	11.19	7.75	1.34	155.59
6.	10.26	6.21	0.41	10.36	5.70	1.51	174.63
7.	13.48	6.08	0.41	10.13	7.49	1.19	138.52
8.	13.22	6.99	0.47	11.64	7.34	1.48	171.62
9.	12.70	6.44	0.43	10.74	7.06	1.39	161.36
10.	11.56	6.31	0.42	10.51	6.42	1.36	157.65
Mean	12.72	6.75	0.45	11.25	7.04	1.36	158.10
s	0.37	0.17	0.01	0.29	0.21	0.03	3.28
s (%)	2.94	2.58	2.58	2.58	3.02	2.08	2.08

δ_b – maximal elongation, F_t – maximal tensile force, σ^b_T – tensile strength, σ^w_T – tensile index, ε_T – maximal strain at break, S_{max} – maximal slope of the curve of force versus elongation, E_T – tensile modulus of elasticity, s – standard deviation

Typical determination of maximal slope S_{max} = 4.2981 N*mm^{-1} of longitudinal loading of longitudinal paper strip of crepe paper of sample 1 from ten realized samples is presented in the Figure 7. Slope was determined on the base of linear regression from the linear part of the tensile diagram. Tensile modulus of elasticity *E* =166.00 MPa was calculated from the equation (3) on the base of S_{max} value. Results of longitudinal loading of the examined longitudinal crepe paper samples are presented in the Table 3. Typical tensile diagram of paper strip of crepe paper of transversal sample 5 from ten realized samples is presented in the Figure 8. Maximal tensile force F_t was 19.37 N and a maximal elongation δ_b was 68.27 mm. Maximal strain at break ε_T = 37.93% was calculated from the equation (6). The tensile strength σ_T^b = 1.29 kN∗m^{-1} was evaluated from the equation (4). Tensile index σ_T^w = 8.61 kNm*kg^{-1} was calculated from the equation (5).

Typical determination of maximal slope S_{max} = 0.1117 N*mm^{-1} of longitudinal loading of transversal paper strip of crepe paper of sample 5 from ten realized samples is presented in the Figure 9. Slope was determined on the base of linear regression from the linear part of the tensile diagram. Tensile modulus of elasticity *E* =4.34 MPa was calculated from the equation (3) on the base of S_{max} value. Results of longitudinal loading of the examined transversal crepe paper samples are presented in the Table 4.

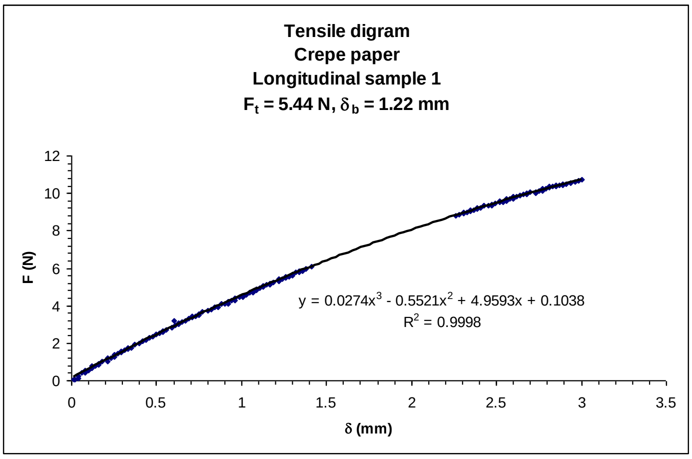

Figure 6. Tensile diagram of crepe paper longitudinal sample no. 1 and values of maximal tensile force F_t = 5.44 N and maximal elongation at break δ_b= 1.22 mm

Obrázok 6. Ťahový diagram pozdĺžnej vzorky krepového papiera č. 1 a hodnoty maximálnej ťahovej sily F_t = 5,44 N a maximálneho predĺženia pri pretrhnutí δ_b = 1,22mm

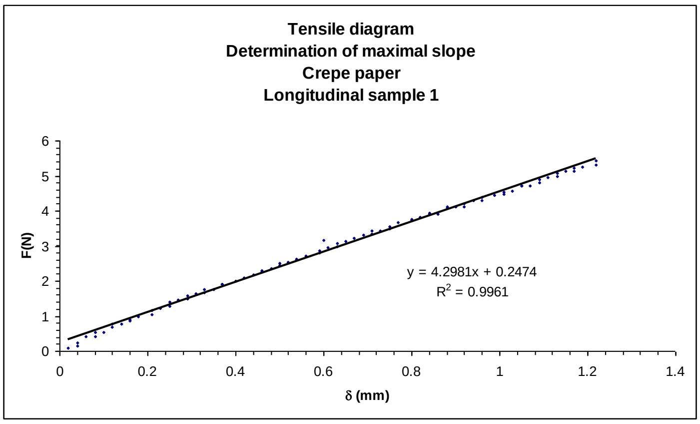

Figure 7. Determination of maximal slope S_{max} = 4.2981 N*mm^{-1}of crepe paper longitudinal sample no. 1

Obrázok 7. Stanovenie maximálnej smernice S_{max} = 4,2981 N*mm^{-1} pozdĺžnej vzorky č. 1 krepového papiera

Mean values of the tensile modulus of elasticity of longitudinal and transversal chickpaper samples were almost equal. Chickpaper mechanical properties in tension are different in the longitudinal and transversal direction of the original paper surface. Mean values of the maximal elongation δ_b and maximal strain at break ε_T of longitudinal crepe paper samples were sixty times smaller than maximal elongation and maximal strain at break of transversal samples.

Table 3. Results of the longitudinal loading of longitudinal samples of crepe paper

Tabuľka 3. Výsledky pozdĺžneho zaťaženia pozdĺžnych vzoriek krepového papiera

Crepe paper	Longitudinal						
Sample	δ_b (mm)	F_t (N)	σ^b_T (kN*m^{-1})	σ^w_T (kNm*kg^{-1})	ε_T (%)	S_{max} (N*mm^{-1})	E_L (MPa)
1.	1.22	5.44	0.36	2.42	0.68	4.30	166.00
2.	1.32	5.44	0.36	2.42	0.73	4.02	156.00
3.	1.07	4.81	0.32	2.14	0.59	4.43	172.00
4.	0.66	2.99	0.20	1.33	0.37	4.55	176.79
5.	0.82	3.81	0.25	1.69	0.46	4.62	179.54
6.	1.23	5.85	0.39	2.60	0.68	4.74	184.02
7.	1.18	4.81	0.32	2.14	0.66	4.28	166.11
8.	1.21	5.94	0.40	2.64	0.67	4.87	179.28
9.	0.99	4.35	0.29	1.93	0.55	4.62	179.56
10.	1.02	4.99	0.33	2.22	0.57	4.97	192.96
Mean	1.07	4.84	0.32	2.15	0.60	4.54	175.33
s	0.07	0.29	0.02	0.13	0.04	0.09	3.30
s (%)	6.08	6.04	6.02	6.02	6.08	2.02	1.88

δ_b – maximal elongation, F_t – maximal tensile force, σ^b_T – tensile strength, σ^w_T – tensile index, ε_T – maximal strain at break, S_{max} – maximal slope of the curve of force versus elongation, E_T – tensile modulus of elasticity, s – standard deviation

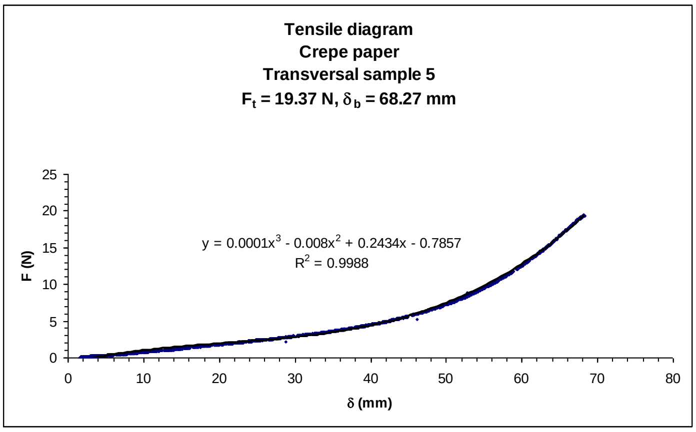

Figure 8. Tensile diagram of crepe paper transversal sample no. 5 and values of maximal tensile force F_t = 19.37 N and maximal elongation at break δ_b= 68.27 mm

Obrázok 8. Ťahový diagram priečnej vzorky krepového papiera č. 5 a hodnoty maximálnej ťahovej sily F_t = 19,37 N a maximálneho predĺženia pri pretrhnutí δ_b = 68,27mm

Mean values of the tensile modulus of elasticity of longitudinal samples of crepe paper were thirty eight times smaller than values of transversal samples. Crepe paper mechanical properties in tension were very different in the longitudinal and transversal direction of the original paper surface. Szewczyk et al. (2006) presented the moduli of elasticity of liner (thickness 0.347 mm) in the range from 2331 MPa to 5346 MPa, fluting (thickness 0.241 mm) ranging from 2070 MPa to 3315 MPa and coated (thickness 0.103 mm) papers ranging from 4009 MPa to 6621 MPa. Moduli were ten times bigger than moduli of measured samples. The explication could be the different tensile velocities.

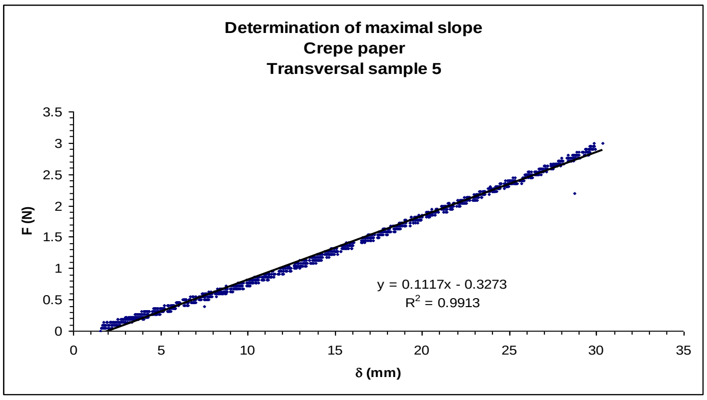

Figure 9. Determination of maximal slope S_{max} = 0.1117 N*mm^{-1}of crepe paper transversal sample no. 5

Obrázok 9. Stanovenie maximálnej smernice S_{max} = 0,1117 N*mm^{-1} priečnej vzorky č. 5 krepového papiera

Table 4. Results of the longitudinal loading of transversal samples of crepe paper

Tabuľka 4. Výsledky pozdĺžneho zaťaženia priečnych vzoriek krepového papiera

Crepe paper			Transversal				
Sample	δ_b (mm)	F_t (N)	σ^b_T (kN∗m^{-1})	σ^w_T (kNm*kg^{-1})	ε_T (%)	S_{max} (N*mm^{-1})	E_T (MPa)
1.	60.77	17.58	1.17	7.81	33.76	0.11	4.35
2.	66.73	18.69	1.25	8.31	37.07	0.12	4.61
3.	63.54	19.82	1.32	8.81	35.30	0.13	5.16
4.	61.73	16.10	1.07	7.16	34.29	0.12	4.55
5.	68.27	19.37	1.29	8.61	37.93	0.11	4.34
6.	67.86	18.42	1.23	8.19	37.70	0.11	4.23
7.	64.26	17.78	1.19	7.90	35.70	0.12	4.49
8.	61.88	17.42	1.16	7.74	34.38	0.12	4.76
9.	65.40	19.73	1.32	8.77	36.33	0.12	4.51
10.	63.78	18.01	1.20	8.01	35.43	0.12	4.53
Mean	64.42	18.29	1.22	8.13	35.79	0.12	4.55
s	0.82	0.37	0.02	0.16	0.46	0.00	0.08
s (%)	1.28	2.01	2.01	2.01	1.28	1.80	1.80

δ_b – maximal elongation, F_t – maximal tensile force, σ^b_T – tensile strength, σ^w_T – tensile index, ε_T – maximal strain at break, S_{max} – maximal slope of the curve of force versus elongation, E_T – tensile modulus of elasticity, s – standard deviation

Szewczyk et al. (2006) used velocity 10 mm*min^{-1} but crepe paper and chickpaper measurements were realized at the velocity 20 mm*min^{-1}. The standard deviations of the quantities were ranging from 1.28% to 7.71% Measurements were relatively exact. The smaller precision of determination of maximal elongation and maximal strain at break was induced by the problems with the measurement and record of the initial values of the force and the elongation by the test stand STENTOR ANDILOG 1000. Shapes of tensile diagrams of longitudinal and transversal samples of chickpaper were very similar, but were quantitatively different. Shapes of tensile diagrams of chickpaper were also similar to the tensile diagrams of longitudinal samples of crepe paper, but also were quantitatively different. Shapes of tensile diagrams of transversal samples of crepe paper were different from all others.

Conclusions

Tensile properties of the chickpaper and crepe paper are important for advisement of mechanical condition of the materials in the chicken breeding. Tensile properties of the papers were studied only in the linear region of deformations.

The force – elongation dependencies of the tensile test allowed a determination of the maximal elongation δ_b, maximal strain at break ε_T and maximal tensile force F_t. Tensile strength $\sigma^b{}_T$ and tensile index $\sigma^w{}_T$ were also evaluated. These parameters were significantly different among longitudinal and transversal samples of both papers, chickpaper and crepe paper.

Tensile modulus of elasticity E of chickpaper for longitudinal and transversal samples were almost equal. Tensile modulus of elasticity E of crepe paper for longitudinal and transversal samples were significantly different.

Tensile modulus of elasticity E of chickpaper for longitudinal and transversal samples and tensile modulus of elasticity E of crepe paper for longitudinal samples were also very similar but tensile modulus of elasticity E of crepe paper for transversal samples were significantly different.

Maximal elongation δ_b of crepe paper for transversal samples were significantly different of all others samples.

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