Descriptive statistics for plane structures of the multilayer matrix for tissue haemostasis and regeneration

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ABSTRACT – REZUMAT

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Bleeding, severe and infected wounds need to be cared for to facilitate recovery and prevent infection. The specific requirements imposed on dressings for the treatment of these wounds depend fundamentally on the type of lesion; moreover, they are based on the creation of an optimal environment that allows epithelial cells to move easily to facilitate regeneration. The objective of the research is to provide a multilayer medical device with composite characteristics, usable for basic medical interventions on superficial burns with thermal origin (flame and melts) occurred on anatomical regions protected by clothes (so except face and eyes). The outer, second and interfacing layers have specific characteristics. Regarding this aspect, 5 variants of woven textile structures were designed and made that differed in the nature of the raw material, the density of the length/fineness of the threads in the weft, the density in the weft and the binding. To characterize the populations of flat structures used to make the first layer of the matrix, methods specific to descriptive statistics were used. The following fundamental statistical indicators were calculated for each of the 3 variables considered defining (mass, thickness and absorption capacity): mean, dispersion and standard deviation; median and quartiles; eccentricity (skewness) and vaulting (kurtosis) for asymmetry and highlighting the cases in which interventions should be performed (on the technological flow or on the programming scheme). The results obtained by the statistical analysis of the groups of results allowed the findings to be generalized to larger populations, so for the whole set from which the respective sample was extracted. Depending on location and the severity of wounds resulting from shooting, explosions or fire (wounds that result in bleeding, impaired vital functions, the impotence of an anatomical segment, celsiene signs, etc.), the first layer of the matrix can be made of woven textile materials. After correlating the physico-mechanical characteristics of the textile structures with the subsequent processes (realization of layer II, layer III and functionalization), the technical and physico-mechanical characteristics of the multilayer matrix will be determined, and the location areas and the field of use (for haemostasis, regeneration of connective tissues or their simultaneous combination) will be established.

Keywords: *dressings, descriptive statistics, textile structures, haemostasis, tissue regeneration*

Statistica descriptivă pentru structurile plane ale matricei multistrat pentru haemostaza și regenerarea țesuturilor

Sângerarea, rănile severe și infectate trebuie îngrijite pentru a facilita recuperarea și a preveni infecția. Cerințele specifice impuse pansamentelor pentru tratarea acestor răni depind fundamental de tipul leziunii; mai mult, ele se bazează pe crearea unui mediu optim care permite celulelor epiteliale să se deplaseze cu ușurință, pentru a facilita regenerarea. Obiectivul cercetării este de a oferi un dispozitiv medical multistrat cu caracteristici compozite, utilizabil pentru intervenții medicale de bază pentru arsuri superficiale de origine termică (flacără și topire), apărute pe regiuni anatomice protejate de îmbrăcăminte (deci cu excepția feței și a ochilor). Straturile exterior, de mijloc și de interfață au caracteristici specifice. În ceea ce privește acest aspect, au fost proiectate și realizate 5 variante de structuri textile ţesute, care se deosebesc prin natura materiei prime, finețea firelor în bătătură, desimea în bătătură și tipul legăturii. Pentru caracterizarea populaţiilor de structuri plane utilizate la realizarea primului strat al matricei s-au folosit metode specifice statisticii descriptive. Pentru fiecare dintre cele 3 variabile considerate definitorii (masă, grosime și capacitate de absorbție) au fost calculați următorii indicatori statistici fundamentali: media, dispersia și abaterea standard; mediana și cuartilele; excentricitatea (asimetria) și vaulting (kurtosis) pentru asimetrie și evidențierea cazurilor în care ar trebui efectuate intervenții (pe fluxul tehnologic sau pe schema de programare). Rezultatele obţinute prin analiza statistică a grupelor de rezultate au permis generalizarea constatărilor la populaţii mai mari, deci pentru întregul set din care a fost extrasă proba respectivă. În funcție de localizare și de severitatea rănilor rezultate din împușcare, explozii sau incendii (răni care au ca rezultat sângerarea, afectarea funcțiilor vitale, impotența unui segment anatomic, semne celsiene etc.), primul strat al matricei poate fi realizat din materiale textile țesute. După corelarea caracteristicilor fizico-mecanice ale structurilor textile cu procesele ulterioare (realizarea stratului II, stratului III și funcționalizarea), se vor determina caracteristicile tehnice și fizico-mecanice ale matricei multistrat și se vor stabili zonele de amplasare și domeniul de utilizare (pentru hemostază, regenerarea țesuturilor conjunctive sau combinarea lor simultană).

Cuvinte-cheie*: pansamente, statistică descriptivă, structuri textile, hemostază, regenerarea țesuturilor*

INTRODUCTION

Wounds are open traumas that entail a discontinuity of the skin or mucous membranes (a factor of continuity). An injury can occur in the event of an accident or after surgery. In general, bleeding, severe and infected wounds should be cared for to facilitate recovery and prevent infection [1].

The specific requirements imposed on dressings for the treatment of these wounds depend fundamentally on the type of lesion. For example, strong exudative lesions require dressings with a high absorption capacity that are capable of removing excess exudate. Another important parameter is the speed of water vapour transmission of membranes and films used as dressings [2]. High values of this parameter can cause excessive wound dehydration, while biomaterials with a low rate of water vapour transmission can cause maceration of the lesion due to excess fluid, causing pain and slowing recovery [1, 3]. The type of lesion and its phase influences the rate of water loss due to evaporation. Thus, healthy skin and minor lesions have a water vapour transmission rate of approximately 150–200 g/m^2 per day, while that of first-degree burns is in the range of 250–300 g/m^2 per day, and wounds with granulation tissue have values between 5000 and 5200 g/m^2 per day.

Furthermore, the dressing must be stable long enough to prevent premature changes, which sometimes disrupt the newly formed tissue and cause patient discomfort. Thus, knowledge of the degradation kinetics of the biopolymeric dressing is essential [5].

When selecting the biomaterial used in the treatment of wounds, factors such as healing time; care costs; frequency of dressing changes; and the need to use other products, such as secondary dressings, antibiotics and analgesics, etc., must also be considered [4, 6]. Sometimes it may be necessary to use more than one product, but in general, this approach should be avoided. Some dressings, such as antimicrobial dressings, may have a negative impact on cell function; therefore, they should be used for a limited time and only in specific cases.

The new generations of dressings are based on creating an optimal environment that allows epithelial cells to move easily for regeneration. Such optimal conditions include a humid environment around the wound, efficient circulation of oxygen to help cells and tissues regenerate, and low bacterial contamination. Other factors that contribute to the development of a wide range of dressings include different types of wounds (e.g., acute, chronic, exuding and dry lesions, etc.) and the fact that no dressing is suitable for treating all wounds. In addition, the wound healing process has several different phases, which cannot be addressed with a single type of dressing. A multilayer medical device with composite characteristics, usable for basic medical interventions on superficial burns with thermal origin (flame and melts) occurred on anatomical regions protected by clothes (so except face and eyes) was developed. The outer layer acts as a carrier, insulator and protector of underlying layers; the second layer has the purpose of managing the liquid composition in the lesion area; the interfacing layer with the lesion must be non-adherent, biologically inert and microporous. The selection of textile structures for layer I is presented. Regarding this aspect, 5 variants of woven textile structures were designed and developed that differentiated in the nature of the raw material, the length density, the fineness of the threads in the weft, the density in the weft and the binding.

MATERIAL AND METHODS

Fabric development

The fabric variants were made using the design parameters presented in table 1.

The yields obtained for weaving are similar to those of weavers that process cotton yarns and cotton-type yarns (85–90%).

These structures can be introduced in the manufacturing process because no special interventions are required for the adjustment, installation, or placement of special devices for braking or tensioning yarns. Related to this aspect, it was considered necessary to characterize the fabric variants in terms of physical and mechanical characteristics, because this allowed the identification of variants that could be used further to make the other layers of the matrix.

Characterization of statistical populations

To characterize the populations of plane structures used to make the first layer of the matrix, methods specific to descriptive statistics were used [7]. Thus, with the help of a specialized program, it was possible to rigorously describe the distributions resulting from the experiments performed in the accredited laboratories of INCDTP. Specifically, the following fundamental statistical indicators were calculated for each of the 3 defined variables (mass, thickness and absorption capacity): mean, dispersion and standard deviation; median and quartiles; eccentricity (skewness) and vaulting (kurtosis) for asymmetry and highlighting the cases in which interventions should be performed (on the technological flow or on the programming scheme). The values are shown in tables 2, 3 and 4.

Additionally, box-plot charts were made that highlight the indicators of level (average, median), dispersion and extreme cases. In figure 1, only the graphs of those variants of structures (for all 3 variables) that indicated the presence of extreme values are presented.

The variables “mass”, “thickness” and “absorption capacity” did not vary greatly in any of the 5 variants studied.

Values with:

– indicative 8 – value 178.5 g/m^2, for variant BZNT1, variable “mass”

Table 1

DESIGN PARAMETERS						
Coding of the woven textile support	Fibrous composition		Fineness/Length density		D_b yarn/ 10 cm	Encrypted link (includes edge encryption, with platinum linking from left to right)
	Warp	Weft	Warp	Weft		
BZNT1	100% bbc	80% bbc/ 20% fibres with ZnO	Nm50/2	Nm68/2	240	Atlas: -(2-6-8-9-11//2-4-9-11-12//1-4-5-7-12// 1-5-7-8-10//2-3-8-10-11//2-3-4-6-11// 1-4-6-7-9//1-7-9-10-12// 2-3-5-10-12//1-3-5-6-8//)-
BBT1	100% bbc	100% bamboo	Nm50/2	Nm34/1	250	Comb 1: -(2-3-7-11//2-4-10-12//1-3-5-9-11// 1-3-4-6-8-10-11-12//2-4-5-7-9-10-12// 1-3-5-9-11//1-4-10-12//)-
BLT1	100% bbc	100% lenpur	Nm50/2	Nm34/1	200	
BAT1	100% bbc	100% acetate	Nm50/2	130dtex	350	Comb 2: -(2-3-5-7-9-11//1-4-5-6-8-10-12//2-3-5- 7//2-3-7//1-3-5-7//1-4-5-6-8-10-12// 2-3-57-9-11//1-3-5-7-9-10-11//1-8- 10-12//2-8-12//2-8-10-12// 1-3-5-7-9-10-11//1-4-6-8-10-12//)-
BBT2	100% bbc	100% bbc	Nm50/2	Nm60/2	255	Plaid: -(2-3-4-5-6-7//1-3-4-5-6-7//2-3-5-7//2-3-4- 5-6-7//1-3-4-5-6-7//1-8-9-10-11-12// 2-8-9-10-11-12//2-8-10-12//1-8-9-10- 11-12//2-8-9-10-11-12//1-3-5-7-9-11// 1-4-6-8-10-12//2-3-5-7-9-11// 2-4-6-8-10-12//1-3-5-7-9-11//1-4-6- 8-10-12//2-3-5-7-9-11//2-4-6-8-10-12// 1-3-5-7-9-11//1-4-6-8-10-12//)-

Table 2

STATISTICS OF BZNT1, BBT1 AND BLT1										
Statistical indicators		Mass			Thickness			Absorption capacity		
		BZNT1	BBT1	BLT1	BZNT1	BBT1	BLT1	BZNT1	BBT1	BLT1
Mean		176.330	169.130	166.860	0.5720	0.5380	0.5720	54.8190	120.2310	117.4900
Median		176.300	169.150	167.100	0.5700	0.5400	0.5700	54.8300	120.2000	117.6000
Std. deviation		0.9878	0.3368	0.5758	0.01033	0.01229	0.00789	0.13715	0.73398	0.58963
Variance		0.976	0.113	0.332	0.000	0.000	0.000	0.019	0.539	0.348
Skewness		0.601	0.723	–1.104	0.272	–0.431	–0.407	-0.487	0.726	0.140
Std. error of skewness		0.687	0.687	0.687	0.687	0.687	0.687	0.687	0.687	0.687
Kurtosis		1.566	0.384	0.475	–0.896	–1.461	–1.074	0.384	–0.406	0.203
Std. error of kurtosis		1.334	1.334	1.334	1.334	1.334	1.334	1.334	1.334	1.334
Minimum		174.8	168.7	165.7	0.56	0.52	0.56	54.55	119.33	116.60
Maximum		178.4	169.8	167.5	0.59	0.55	0.58	55.00	121.50	118.60
Percentiles	25	175.725	168.800	166.475	0.5600	0.5275	0.5675	54.7450	119.6400	116.8750
	50	176.300	169.150	167.100	0.5700	0.5400	0.5700	54.8300	120.2000	117.6000
	75	176.850	169.275	167.250	0.5800	0.5500	0.5800	54.9250	120.6750	117.8000

– indicative 4 – value 169.8 g/m^2, for the BBT1 variant, the "mass" variable

are located at a distance of 1.5–3 box lengths and should not be excluded from the series of determinations.

Interpretation of the statistical data:

1. The variables "mass" and "absorption capacity" for variants BBT1, BLT1, RVN1, as well as "thickness" variants BLT1, RVN1, BAT1 has a distribution of 50% of the values directed to the right; in addition, the median being directed to the upper edge of box, so high values are predominant. For the variables

Table 3

STATISTICS OF BAT1 AND BLT1 AND BBT2							
Statistical indicators		**Mass**		**Thickness**		**Absorption capacity**	
		BLT1	**BBT2**	**BLT1**	**BBT2**	**BLT1**	**BBT2**
Mean		136.130	184.132	0.4510	0.7110	109.6600	121.9880
Median		136.250	184.050	0.4500	0.7100	109.7500	121.8500
Std. deviation		0.5376	0.5618	0.00738	0.00816	0.56608	0.33960
Variance		0.289	0.316	0.000	0.000	0.320	0.115
Skewness		–0.716	0.616	–0.166	0.000	–0.436	0.631
Std. error of skewness		0.687	0.687	0.687	0.687	0.687	0.687
Kurtosis		–0.140	–0.943	–0.734	–1.393	–0.541	–1.287
Std. error of kurtosis		1.334	1.334	1.334	1.334	1.334	1.334
Minimum		135.1	183.5	0.44	0.70	108.70	121.60
Maximum		136.7	185.0	0.46	0.72	110.50	122.50
Percentiles	25	135.800	183.650	0.4475	0.7000	109.2000	121.7575
	50	136.250	184.050	0.4500	0.7100	109.7500	121.8500
	75	136.700	184.700	0.4600	0.7200	110.1000	122.4125

“mass” and “absorption capacity” in the case of the BBT2 variant, the median is directed towards the lower edge of the box, so it can be stated that the distribution is directed to the left and the small values are predominant.

2. Distribution form indicators for woven textile variants, respectively:

Variant BZNT1

a) 50% of the values obtained for the mass are below 176.3 g/m^2, 25% being in the range [176.3; 176.8] and 25% are over 176.8 g/m^2.

b) 25% of the values obtained at thickness are below the value of 0.56 mm and 25% are above the value of 0.58 mm, 50% of the values being included in this interval defined by the minimum and maximum value.

c) 25% of the values of absorption capacity are below 54.7%, 50% are in the range [54.7; 54.9] and 25% are over 54.9%.

d) The skewness indicators have the values of 0.601 for mass and 0.272 for thickness, which highlights the extent to which the average moves away from the median; implicitly, the normal distribution curves moved away from the middle, moving to the right. In the case of the variable “absorption capacity”, the curve moved to the left, and the skewness value was negative.

e) Kurtosis indicators have positive values, 1,566 for mass and 0.384 for absorption capacity. The curve is leptokurtic and has a negative value for the variable thickness (–0.896), the curve is platykurtic.

Variant BBT1

a) 25% of the values obtained for the mass are below the value of 168.8 g/m^2, 25% being in the range [168.8; 169.1], and 25% are in the range [169.1; 169.3] and 25% are over 169.3 g/m^2.

b) 50% of the values obtained in thickness are in the range [0.528; 0.55], 25% being below the determined minimum value and 25% being above the determined maximum value.

c) 25% of the values of the absorption capacity are below 119.6%, 50% are in the range [119.6; 120.7] and 25% are over 120.7%.

d) The skewness indicators have positive values for mass and absorption capacity, and the curves move to the right and have negative values for thickness, so the curve moves to the left.

e) The kurtosis indicators have a positive value of 0.384 for the mass, so the curve is leptokurtic (small scattering of values) and respectively has negative values for the variables thickness (–1,461) and absorption capacity (–0,406); therefore, the curves is platykurtic.

Variant BLT1

a) 50% of the values obtained for the mass are in the range [166.48; 167.25], 25% being below the minimum value and 25% being above the determined maximum value.

b) 50% of the values obtained at thickness are below the value of 0.57 mm, 25% are above the value of 0.58 mm, and 25% are located in the range [0.57; 0.58].

c) 25% of the absorption capacity values are below 116.87%, 50% are in the range [116.87; 117.8] and 25% are above the upper limit of the range.

d) The skewness indicators have positive values for the variable absorption capacity, the curve moving to the right. For the other two variables the values are negative, –1.104 for mass and –0.407 for thickness, the curves moving to the left.

e) The kurtosis indicators have positive values of 0.475 for mass and 0.203 for absorption capacity, the curve is leptokurtic, and the variable thickness is negative (–1.074), the curve is platykurtic (large spread of values).

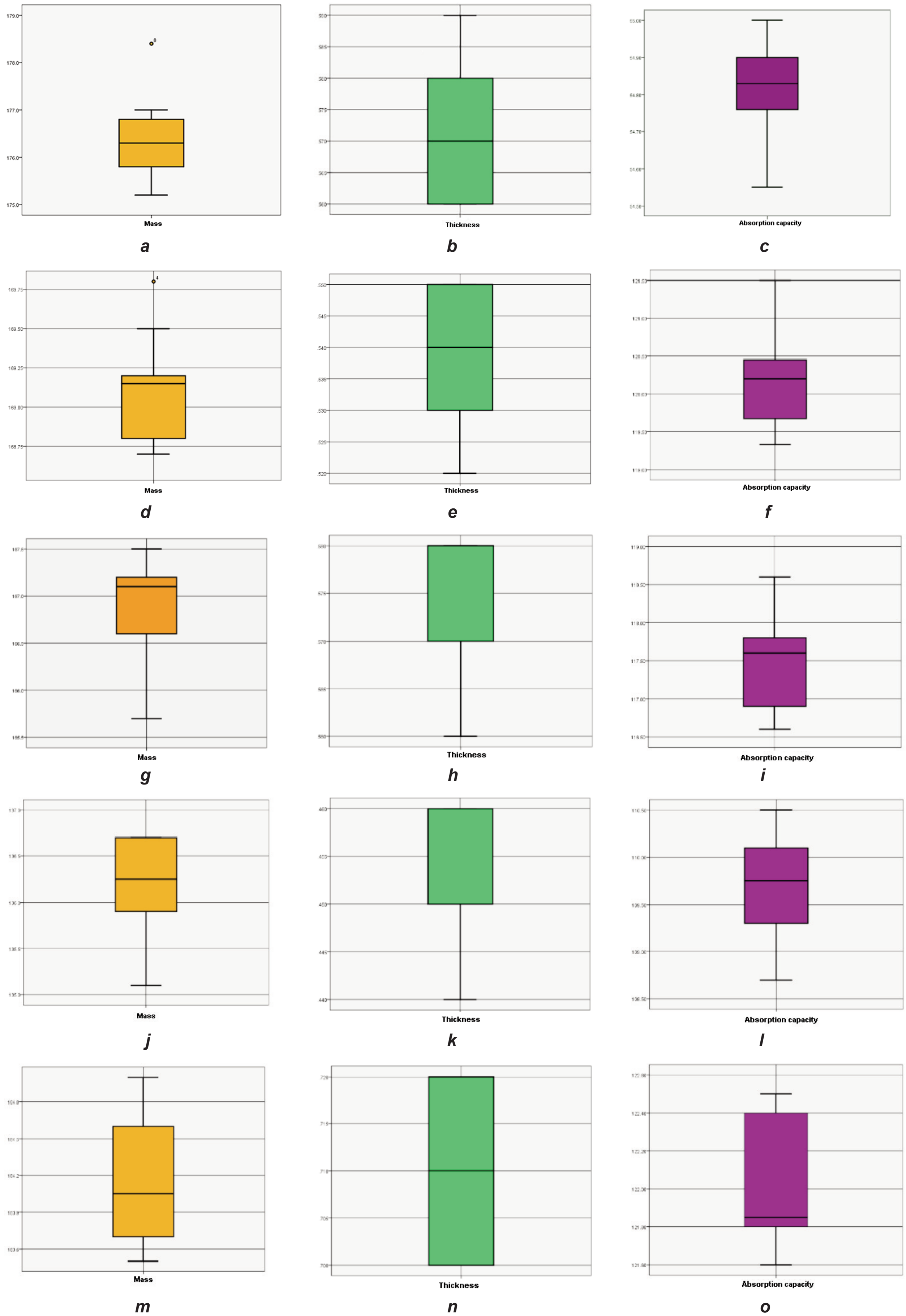

Fig. 1. Boxplot charts for: *a* – BZNT1 mass; *b* – BZNT1 thickness; *c* – BZNT1 absorption capacity; *d* – BBT1 mass; *e* – BBT1 thickness; *f* – BBT1 absorption capacity; *g* – BLT1 mass; *h* – BLT1 thickness; *i* – BLT1 absorption capacity; *j* – BAT1 mass; *k* – BAT1 thickness; *l* – BAT1 absorption capacity; *m* – BBT2 mass; *n* – BBT2 thickness; *o* – BBT2 absorption capacity

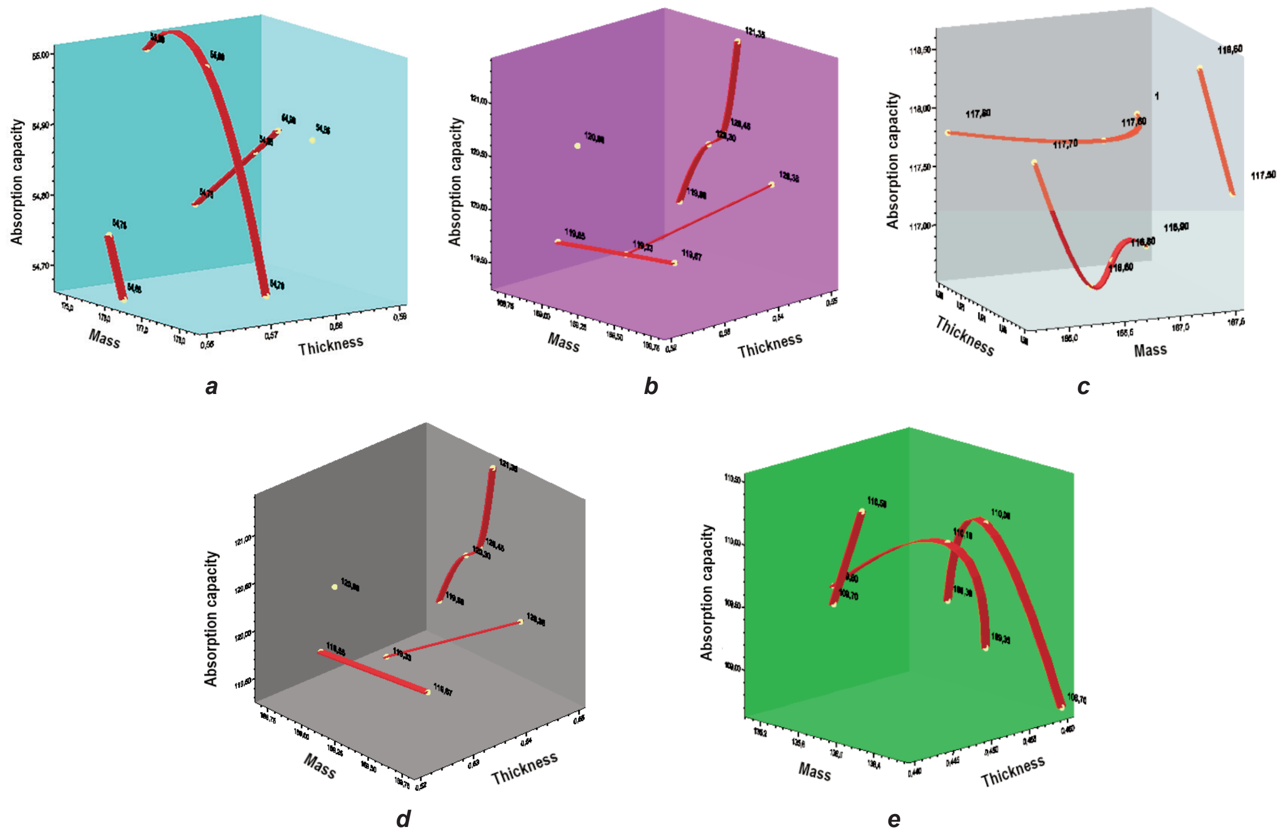

Fig. 2. Band graphs for: *a* – BZNT1; *b* – BBT1; *c* – BLT1; *d* – BAT1; *e* – BBT2

Variant BAT1

a) 25% of the values obtained for the mass are below 135.8 g/m^2, 25% being in the range [135.8; 136.3], 25% are in the range [136.3; 136.7] and 25% are over 136.7 g/m^2.

b) 50% of the thickness values obtained are in the range [0.448; 0.46], 25% being below the determined minimum value and 25% are above the maximum value.

c) 25% of the values of the absorption capacity are below 109.2%, 50% are in the range [109.2; 110.1] and 25% are over 110.1%.

d) The skewness indicators have negative values for all 3 variables, and the curves move to the left.

e) Kurtosis indicators have negative values of –0.140 for mass, –0.734 for thickness and –0.541 for absorption capacity, which proves that there is a large spread of values; hence, the curve is platykurtic.

Variant BBT2

a) 25% of the values obtained for the mass are below 183.6 g/m^2, 25% being in the range [183.6; 184.0], 25% are in the range [184.0; 184.7] and 25% are over 184.7 g/m^2.

b) 50% of the values obtained in thickness are in the range [0.70; 0.72], 25% being below the determined minimum value and 25% being above the determined maximum value.

c) 25% of the values of the absorption capacity are below 121.7%, 50% are in the range [121.7; 122.4] and 25% are over 122.4%.

d) The skewness indicators have positive values for all 3 variables, so the curves move to the right. It should be emphasized that, in the case of the thickness variable, the value of 0 that was obtained proves that there are no differences between the mean and the median, with the distribution being normal.

e) Kurtosis indicators have negative values for all 3 variables, and the curves are platykurtic, so there is a large spread of values.

Interactive band-type graphics

The representation was made using band graphs, in which the interpolation was performed using the 3rd degree Lagrange interpolation polynomial [7, 8]. It was not considered necessary to increase the degree of the polynomial (ex. 5) because with the increase in the degree of the interpolation polynomial, the error of approximation in the points far from them increased (the function samples were preserved, and there was a polynomial variation in the intervals between the points corresponding to the average). In addition, the use of the 3rd degree Lagrange polynomial was considered to lead to a reasonable trade-off between accuracy and complexity (figure 2). The coefficients of the Lagrange polynomial were determined based on the conditions of coincidence between the values of the interpolation function and the interpolation polynomial at the given discrete set points [8].

CONCLUSIONS

Statistical mathematical analysis was used to select textile structures for a multilayer medical device for treating burns.

The results obtained by the statistical analysis of the groups allowed the findings to be generalized to larger populations, i.e., the entire set from which the respective sample was extracted.

Depending on the location and the severity of wounds resulting from shooting, explosions or fire (wounds that result in bleeding, impaired vital functions, the impotence of an anatomical segment, celestine signs, etc.), the first layer of the matrix can be made of woven fabrics.

After correlating the physico-mechanical characteristics of the textile structures with the subsequent processes (realization of layer II, layer III and functionalization), the technical and physico-mechanical characteristics of the multilayer matrix will be determined, and the location areas and the field of use (for haemostasis, regeneration of connective tissues or their simultaneous combination) will be established.

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