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Natural and safe dyeing of curing clothing intended for patients with dermatoses

Naturalne i bezpieczne barwienie odzieży leczniczej przeznaczonej dla osób z chorobami skóry

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SUMMARY

Introduction. *The Institute of Natural Fibers and Medicinal Plants has been carrying out complex research connected with application of natural dyes on knitted fabrics and fabrics. The paper presents the results of the part of the research conducted at the Institute, related to the Project BIOAKOD – Bioactive curing clothing based on natural fibers.*
Aim. *The aim of the project's task 3 was to develop organic cotton and knitted linen dyeing technology using the extracts obtained from plants.*
Material and methods. *Plant extracts depending on the content of active substances and their precious ingredients they can have the following properties: medicinal, soothing, moistening, anti-inflammatory, regenerative, antiviral, antifungal, antioxidant and protection against UV radiation. Several plants were tested during the project realization. Finally, were obtained the extracts from the following plants: Madder Rubia tinctorium L., Dyer's greenweed Genista tinctoria L, Weld Reseda luteola L., Dyer's coreopsis Coreopsis tinctoria L., Oak Gall Quercus infectoria Oliv, Chebulic Myrobalan Terminalia chebula L.*
Results. *In the final phase the 9 colours were chosen. The dyeing was performed in semi-industrial conditions in the factory Marko-Kolor. The registered patent is also the effect of this project grant.*
Conclusions. *The interesting range of colours was achieved, and tested extracts showed healing properties.*

Keywords: natural dyestuff, medicinal fabrics, curing clothing, plant extracts

STRESZCZENIE

Wstęp. *Instytut Włókien Naturalnych i Roślin Zielarskich prowadzi kompleksowe badania związane z zastosowaniem naturalnych barwników do barwienia dzianin i tkanin. Przedstawione wyniki są rezultatem prowadzonych w Instytucie badań związanych z realizacją tematu: Bioaktywna odzież o właściwościach pielęgnacyjno-leczniczych.*
Cel pracy. *Celem zadania 3 było opracowanie technologii barwienia bawełny organicznej i dzianin ekstraktami uzyskanymi z roślin barwierskich.*
Materiał i metody. *Ekstrakty roślinne w zależności od zawartości substancji czynnych i ich cennych składników mogą mieć następujące właściwości: lecznicze, łagodzące, zwilżające, przeciwzapalne, regenerujące, przeciwwirusowe, przeciwgrzybicze, przeciwutleniające i chroniące przed promieniowaniem UV. Podczas realizacji projektu przetestowano kilka roślin posiadających te cenne właściwości. Ostatecznie uzyskano ekstrakty z następujących roślin: Marzanna Rubia tinctorium L., Janowiec barwierski Genista tinctoria L., Rezeda Reseda luteola L., Nachyłki barwierskie Coreopsis tinctoria L., Dębianki Quercus infectoria Oliv, Migdałecznik chebułowiec Terminalia chebula L.*

Wyniki. *W końcowej fazie projektu do wykonania kolekcji odzieży prozdrowotnej wybrano 9 kolorów. Barwienie przeprowadzono w warunkach półprzemysłowych w fabryce Marko-Kolor. Efektem projektu jest przyznany patent.*
Wnioski. *Uzyskano interesującą gamę kolorów, a przetestowane ekstrakty wykazały właściwości lecznicze.*

Słowa kluczowe: barwienie naturalne, rośliny barwierskie, ekstrakty roślinne, odzież lecznicza

Introduction

The objective of the project was obtaining and using natural dyestuffs for design curing clothes. The studies were based on earlier experimental works of Natural Dyeing Laboratory and Laboratory of Physiological Influence of Textiles on Human Body, Institute of Natural Fibres and Medicinal Plants in Poznań (1-3).

Recently, there has been revival of the growing interest on the application of natural dyes on natural fiber in developed societies, where a lot of attention is paid to healthy lifestyle, which includes diets, physical activity and also comfort related to clothing.

The use of non-toxic and eco-friendly natural dyes on textiles has become a matter of significant importance for research and healthy life.

The Institute has been carrying out studies on clothing influence on human organism. We feel better in fabrics made of natural raw materials. Additional feature of dyeing the fabrics with dyes of plant origin will increase their attractiveness, comfort of wearing, and will also have effect on human frame of mind. This time the studies were extended to test the dyed fabrics on people with different dermatoses (1).

Currently, there are about two thousand plant species considered as medicinal, which can serve as sources for both pharmaceutical and cosmetic industries. They also show moisturizing, softening and soothing properties. They protect skin against sun rays, whiten it and diminish discolourations, stimulate blood circulation in capillaries and are characterized with toning and astringent properties.

Natural dyes and pigments obtained from plants, vegetables, bark of trees are being looked as an eco-solution and eco-friendly dyes. Plant extracts contain tannins, flavonoids, saponins, essential oils, mucilage, vitamins and many other valuable nutritional substances. They have various properties, e.g. medicinal, soothing, caring, and disinfecting. Finally, 20 species of dye plants of afore mentioned properties were selected for the project.

Aim

The main objective of the study was to develop an eco-friendly method of dyeing fabrics and knittings with extracts obtained from plants. More than 50 different plant materials were used for dyeing. Complex studies on the use of natural dyestuffs in textile industry are a completely unique development.

Since 2000 studies have been conducted on application of natural dyestuffs in unique collections of fabrics. Experiments made on linen and silk fabrics proved the possibility of obtaining a wide range of colours. In Poland such studies have not been carried out for years and the Natural Dyeing Lab. "Natural Art" is the only centre of the kind.

Further stage of the works included moving from laboratory to semi-industrial scale and implementation of the developed technology at the manufacturing plant Marko-Color co.

Material and methods

Plants

In the study the following plants were used, e.g.: French marigold *Tagets species* L., Madder *Rubia tinctorium* L. (fig. 1b), Dyer's greenweed *Genista tinctoria* L. (fig. 1b, c), Weld *Reseda luteola* L., Dyer's camomile *Anthemis tinctoria* L., Dyer's coreopsis *Coreopsis tinctoria* L. (fig. 1a), Coreopsis *Coreopsis grandiflora* L., Woad *Isatis tinctoria* L. Indigo Indigofera tinctoria, Logwood and others.

Materials:

- Sample A – knitted linen 100% (fig. 2a),
- Sample B – knitted linen 100%, premordating – gall oak,
- Sample C – knitted linen/4% elastane, premordating – gall oak (fig. 2b),
- Sample D – organic cotton (fig. 2c).

In cooperation with Marko-Kolor Co. manufacturer a palette of colours were selected for which the dyeing processes were to be scaled-up from laboratory to industrial conditions (tab. 1).

Trials of preliminary treatment of the raw materials for dyeing (stage 1)

The first stage of the task was to develop of a technology for preparing the fabrics and knitting for dyeing. The cotton fabric and linen knitting

Fig. 1a-c. Coreopsis (*Coreopsis tinctoria* Nutt) (a), Madder (*Rubia tinctorium* L.) (b), Dyer's greenweed (*Genista tinctoria* L.) (c) – Experimental farm of Institute of Natural Fibres and Medicinal Plants, Petkowo 2013, 2014

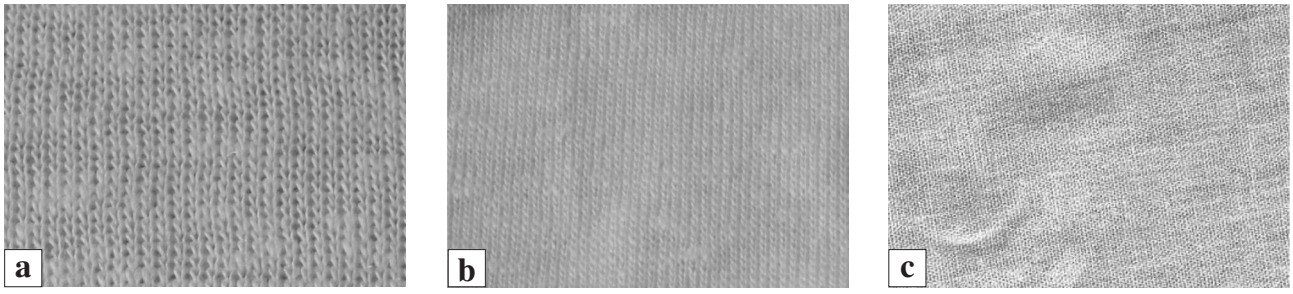

Fig. 2a-c. Knitted linen 100% (a), knitted linen/4% elastane (b), organic cotton (c)

Tab. 1. Result of tests woven fabric and knit fabric from BIOAKOD project

Samples		Mass per unit area (g/m²)	Thread density (No of threads/ 10 cm)	Hygroscopicity (%)		Speed of water sorption (s)	Air permeability (mm/s)	Thermal resistance (m² C/W)	Water vapor resistance (m² Pa/W)
				at 65% humidity	at 100% humidity				
Knit fabric – 100% linen	course	225	73	8.7879	15.0928	292	2654	0.0340	5.0094
	wale		72						
Knit fabric – 100% linen after washing	course	249	82	9.2793	16.3185	30	1718	0.0459	5.3773
	wale		75						
Knit fabric – linen/elastane	course	166	135	7.5264	14.6314	17	1585	0.0340	4.8276
	wale		114						
Knit fabric – linen/elastane after washing	course	178	140	8.6974	15.4800	3	1776	0.0358	4.4259
	wale		114						
Fabric – organic cotton	warp	151	338	6.9472	12.5115	10	309	0.0322	3.8816
	weft		209						
Fabric – organic cotton after washing	warp	159	213	7.9989	12.8611	4	256	0.0276	3.9986
	weft		333						

were treated for obtaining the desired evenness and intensity of dyeing. To achieve this, pretreatment processes were carried out labeled as processes A, B and C.

A. Pre-washing 40°C/30 min:
   – Rucogen WBL50 – 0.5 g/l.
B. Pre-washing 95°C/30 min:
   – sodium hydroxide 2 g/l,
   – Viscavin GVN – 1 g/l.
C. Bleaching 95°C/30 min:
   – sodium hydroxide 2 g/l,
   – Viscavin GVN – 1 g/l,
   – hydrogen peroxide 35% – 5 g/l,

Organoleptic assessment of the dyed materials indicated that the most effective are processes B and C. The knitting prepared with the A recipe appeared to dye in uneven way. Finally, for the further stages of the experiments the B and C methods were selected and acidification with acetic acid. The materials prepared in that way were later pre-treated with plant materials i.e. gall, myrobalan and oak bark in processes labeled as 3A, 3B and 3C.

Pretreatment (stage 2)

Before dyeing three natural materials were selected for mordanting the fabrics and knitting, which materials are characterized with high amounts of tannins. The mordanting materials were: Chebulic Myrobalan (*Terminalia chebula* Retz), Oak Gall (*Quercus infectoria* Oliv.) and Oak Bark (*Ouercus cortex*).

Chebulic Myrobalan (*Terminalia chebula* Retz) has antibacterial, antiviral and antifungal properties (4, 5). Thanks to the wealth of its ingredients, it is used in making therapeutic infusions for rinsing the mouth, throat, and eyes. Drugs containing Chebulic Myrobalan lower cholesterol levels, regulate metabolism and digestive disorders, are used in the treatment of dysentery, and auxiliary and HIV infections. *Terminalia chebula* Retz contains 58-60% of tannin compounds, which makes it a valuable dye and mordant. It is the source of yellow color.

Oak Galls (*Quercus infectoria* Oliv.) contain tannic (6) and gallic acid (7). Gallnuts are used to obtain tannin, which allows for better dyeing of fabrics and is used in tanning. In some galls the compounds (tannins) constitute half, or even more of the substance's dry matter. The tannin compound is gallotannin, which is an ester of glucose, ellagic and gallic acid. Gallnuts, which are widely used in medicine, usually come from oaks. They have an astringent, sedative, antipyretic and antidiabetic effect, and are widely used in the medical and pharmaceutical industries. Galls give black, navy blue and brown colors (6).

Oak Bark (*Ouercus cortex*) is one of the most commonly known plant materials used in medicine. It is used in treatment of inflammations of skin, oral mucosa, as astringent agent in skin and mucosa inflammations, skin lesions, frostbite and mild burns. These properties result from the presence of tannins (catechin, epicatechine, gallcatechine), flavonoids, resin substances and mineral salts.

3A. Treatment in Chebulic Myrobalan:
   – alum 1.27 g/l
   – Chebulic Myrobalan 1%
   Cotton fabric 100% and linen knit 100% – amount 530 g
   Liquor ratio 1:12
   Pre-treatment time (mordating) 90 min
   Temp: 80°C (gradient 1°C/min).

3B. Treatment in Oak Galls:
   – alum 1.75 g/l
   – Oak Gall 0.2%
   Liquor ratio 1:15
   Cotton fabric 100% and linen knit 100% – amount 660 g
   Pre-treatment time (mordating) 90 min
   Temp: 80°C (gradient 1°C/min).

3C. Treatment in Oak Bark:
   – alum 1.75 g/l
   – Oak Bark 0.1%
   Liquor ratio 1:15
   Cotton fabric 100% and linen knit 100% – amount 660 g
   Pre-treatment time (mordating) 90 min
   Temp: 80°C (gradient 1°C/min).

Dyeing (stage 3)

For the experimental dyeing of linen knit and cotton fabric we used the extracts of the following plants: plains Coreopsis (*Coreopsis tinctoria*), Madder (*Rubia tinctoria*), Weld (*Reseda luteola*), Dyer's greenweed (*Genista tinctoria*) and Logwood (*Hematoxylum campechianum*).

The preliminary palette of colours consisted of 30 colours. The colours prepared were shades of pale salmon pink, salmon pink, cream, peach, dirty pink, claret, apricot, pale orange, light yellow, yellow, lemon, light olive and purple (7-9).

In terms of material dyeability, consumption of mordants and plant extracts and evenness of the dyed material the most satisfying results were obtained with running the process at temperature of 95°C/30 min-80°C/20 min, and heating by 1°C/min.

After the process of dyeing with plant extracts it was observed that the obtained colours on the mordanted fabrics are more intensive and evenly

dyed. The most effective turned out to be Oak Gall and Chebulic Myrobalan, which were used for further studies. The cotton fabrics was relatively thick and in order to avoid unevenness and stains during dyeing additives and antiwrinkling agent were used. Unfortunately, when the additives agent was added to the baths with plant extracts and alum, the agent gellated and precipitated from the bath. In order to avoid wrinkling a finishing agent for cellulosic fibres was used. No conflict between the agents and plant extracts was observed, contrary, application of the agents and extracts gave even dyeing effect.

The agent was used at the dose at 1.0 g/l of dyeing baths. During prewashing another agent –Viscavin GVN – was used at the dose of 1 g/l.

For the experimental dyeing of linen knit and cotton fabric the following plant extracts were applied: Coreopsis (*Coreopsis tinctoria*), Madder (*Rubia tinctorium*), Weld (*Reseda luteola*), Dyer's greenweed (*Genista tinctoria*) and Logwood (*Hematoxylum campechianum*). The preliminary colour palette contained 30 colours: shades of pale salmon pink, cream, peach, dirty pink, claret, apricot, pale orange, light yellow, yellow, lemon, light olive and purple.

Results

Based on the prepared palette of the dyed samples and the results of washing and light resistance tests, 9 colours were selected for final dyeing of the linen/elastane knit, 100% linen knit and cotton fabric.

The last stage of the study, i.e. dyeing at semi-industrial scale the following plant extracts were taken: two Madder extracts – Madder N and Madder D.

Madder N gave colours labeled as: 8.3; 8.4 and Madder D: 2.16, Coreopsis gave colours: 2.8; 7k; 15 and Dyer's greenweed gave colours: 10 and 17.2.

Dyeing of fabrics according to the palette chosen by a designer and to the developed recipes was carried out at Marko-Kolor Co. Then, the knits and fabrics were tambled finishing and stabilized. Because of later application of microcapsules on the dyed knits and fabrics, no further finishing process, softening and fixing, were applied.

The dyed linen knits and cotton fabrics were evaluated for resistance to: washing: acc. to PN-EN ISO 105-C06: 2010 met. C1S, artificial light: acc. to PN--EN-ISO 105-B02:2013 met. A1M, acidic sweat: acc. to PN-EN ISO 105-E04 2013 and alkaline sweat: acc. to PN-EN ISO 105-E04 2013.

The table 2 shows resistance to washing and light of fabrics and knittings used in BIOAKOD project without using chemical fixing agents that are used in dyeing industry. This was in line with the project objective to use as little as possible of chemical agents. The best light resistance was achieved for the Madder extracts, namely, Madder D and Madder N. In case of resistance to washing the best results were obtained for Coreopsis and Dyer's greenweed.

The table 3 shows the results of washing fastness and sweat after using the fixing agents. In many cases a slight change in colour was observed. The values of washing resistance increased slightly.

The table 4 presented the measurements of the colour in CIELab system. There are 15 samples of fabrics – linen/elastane knit fabrics, 100% linen knit fabric and organic cotton. The colour numbers was given in the projects for different.

CIE *L*a*b** (CIELab) is a color space specified by the International Commision on Illumination. This system describes all the colors visible to the human eye and was created to serve as a device-independent model to be used as a reference. The parameters are colourfulness, saturation, lightness, and brightness (9).

Discussion

Natural dyeing techniques required a vast knowledge not only related to the dyeing of fabrics but also to preparing them for dyeing. It was important to know the plants and colours, which could be obtained from them using different mordants. The dyeing process lasted longer than nowadays and was conducted in a multistage manner. The present time, which is characterized by fast consumption and seasonally changing fashion, colour does not have to be lasting for years. In the twentieth century, the historical techniques were slowly dying out. However, at the turn of the 20th and 21st centuries, the positive effect of natural fiber fabrics dyed with plant extracts on the human organism began to be noticed. These interests combine with the general trends in increasing use of natural resources, which often are characterized by health-promoting features and many possibilities of application in fashion and design. Individual compounds in plants used to make creams as well as for dyeing fabrics affect the human skin. In highly developed societies interest in fabrics from eco-friendly natural fibres is constantly growing. Their combination with colours obtained from plants increases their value. The plants contain compounds with cosmetic and medical properties, which positive effect has been known thousands years ago in Chinese and Indian medicine.

This medical system concerns not only knowledge of the longevity achieved through precise diagnosis and knowledge of the power of foods and herbs, but also the understanding of how to find harmony within

Tab. 2. Washing and light resistance of the colours selected in the project on three materials

Colour no.	Plant extract	Percent of extract	Material	Washing resistance			Resistance to light
				sample	cotton	wool	
17.2	Dyer's greenweed	7%	Linen/elastane	3/4	4	4/5	1/2
10	Dyer's greenweed	7%	Linen/elastane	3/4	3/4	4/5	1/2
2.16	Madder D	15%	Linen/elastane	3/4	3/4	4/5	4
8.4	Madder N	7%	Linen/elastane	3/4	3	3	3/4
7k	Coreopsis	5%	Linen/elastane	4/5	4/5	4/5	3
17.2	Dyer's greenweed	7%	100% linen knit	4	5	5	1
10	Dyer's greenweed	7%	100% linen knit	4	4	5	1/2
2.16	Madder D	15%	100% linen knit	3/4	4	5	3/4
8.4	Madder N	7%	100% linen knit	2/3	4/5	4/5	3/4
2.8	Coreopsis	1%	100% linen knit	4	5	4/5	4
15	Dyer's greenweed	7%	Organic cotton	3-4	4-5	5	3/4
2.16	Madder D	15%	Organic cotton	3	4	4/5	3/4
8.4	Madder N	7%	Organic cotton	4	2-3	3	3/4
10	Dyer's greenweed	7%	Organic cotton	4	5	5	1
8.3	Madder N	7%	Organic cotton	3	3/4	4	3/4

Tab. 3. Washing resistance of selected colours after application of fixing agents

Colour no.	Plant extract	Percent of extract	Material	Washing fastness after using fixing agents			Sweat resistance after using fixing agents	
				change of hue	cotton	wool	acidic	alkaline
17.2	Dyer's greenweed	7%	Linen/elastane	4	4/5	5	5	5
10	Dyer's greenweed	7%	Linen/elastane	4	4/5	4/5	5	5
8.4	Madder N	7%	Linen/elastane	5	4/5	4/5	4/5	4/5
7.K	Coreopsis	5%	Linen/elastane	4/5	5	5	5	5
17.2	Dyer's greenweed	7%	100% linen knit	4/5	5	5	5	5
8.4	Madder N	7%	100% linen knit	5	4/5	4/5	5	4/5
17.2	Dyer's greenweed		Organic cotton	4	5	5	5	5
15	Dyer's greenweed	7%	Organic cotton	4/5	4/5	4/5	5	5
8.4	Madder N	7%	Organic cotton	4/5	4/5	4/5	4/5	4/5
10	Dyer's greenweed	7%	Organic cotton	4	4/5	4/5	5	4/5

Tab. 4. CIELab values of dyed samples

No.	Extract	%	Fabric	Spectrophotometric result				
				L*	A*	B*	C*	h°
17.2	Dyer's broom	7%	Linen/elastane	10.7	-2.9	44.8	44.9	93.7
10	Dyer's broom	7%	Linen/elastane	75.7	1.5	25.2	25.3	86.7
2.16	Madder root D	15%	Linen/elastane	65.8	18.6	12.6	22.5	34.2
8.4	Madder root N	7%	Linen/elastane	48.4	28.5	13.1	31.3	24.7
7.K	Coreopsis	5%	Linen knitwear 100%	85.1	4.5	27.2	24.6	80.5
17.2	Dyer's broom	7%	Linen knitwear 100%	73.4	-1.4	49.7	49.8	91.6
10	Dyer's broom	7%	Linenknitwear 100%	82.0	-4.1	23.8	22.3	94.6
2.16	Madder root D	15%	Linenknitwear 100%	66.3	15.2	12.3	19.6	39.0
8.4	Madder root N	7%	Linen knitwear 100%	48.4	28.5	13.1	31.3	24.7
2.8	Coreopsis	1%	Linen knitwear 100%	81.4	3.4	26.1	26.3	82.5
15	Dyer's broom	7%	Organic cotton	74.3	-4.5	34.4	34.7	97.4
2.16	Madder root D	15%	Organic cotton	63.1	17.3	15.4	20.1	34.9
8.4	Madder root N	7%	Organic cotton	53.7	23.2	10.5	25.2	22.8
10	Dyer's broom	7%	Organic cotton	84.0	-3.3	25.0	25.3	97.5
8.3	Madder root N	7%	Organic cotton	53.8	23.3	10.7	25.6	24.7

L* – lightness; a* – redness; b* – yellowness; C* – chroma; h° – hue angle

the body and unity with surrounding. Also Ayurveda teaches life in harmony with nature, simplicity and contentment. It provides tips on live in a state of balance by combining creativity and happiness, so that it is easier to overcome psychological problems. Ayurveda is a science of health. Asian medicine is based on profound knowledge of using herbal plants. Many of these plants are the source of beautiful, vibrant colors. Various bioactive compounds are included in the plants: glycosides, tannins, essential oils, sluices and many others. They are characterized various properties, for example medicinal, soothing, caring, and disinfecting. From this point of view they are well known for their curative properties.

Conclusions

The herbal plants, thanks to the content of such components as: polysaccharides, flavonoids, mucilage, tannins, saponins, silica acid, trace elements and phytohormones, are characterized with a wide spectrum of activity. Therefore they find wider use in cosmetic industry and medicine. These complexes, by stimulating cell growth, accelerating anabolism of DNA and proteins and by their anti-oxidant properties, can slow down skin ageing. Among the materials exceptionally effective in combating this skin defect, there are complexes containing flavonoids, which strengthen and tone blood vessels, normalize permeability of the capillaries and their brittleness, strengthen lymphatic vessels and improve circulation. The plant extracts used for dyeing linen knittings and for organic cotton had positive effect on affected skin.

The tests of antibacterial activity against *Staphylococcus aureus* of the samples dyed with Madder, Dyer's greenweed and Coreopsis showed reducing bacteria activity.

The skin of women with dermatoses, during wearing of the tested clothes showed improvement, it was more moisturized, smoother and the skin lesions were significantly limited.

Patent submission has been filed under number P 411869 (10). Our results were awarded four times at different exhibitions – Warsaw, Brussels and Nuremberg.

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10. Patent submission has been filed under number P 411869. Odzież działająca jak suplement opatrunku w terapii chorób dermatologicznych. (Apparel supplement acting as a dressing for the treatment of dermatological diseases).

Konflikt interesów
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Brak konfliktu interesów
None

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