T-SHIRTS – AN OVERVIEW AND COMMENTS ON PRICE RANGE, FUNCTIONAL MATERIALS AND EUROPEAN PRODUCTION

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Abstract: *The T-shirt is probable the most used and the most versatile piece of cloth. With this background, the actual paper gives an overview on different types of T-shirts offered on the German market during the spring and summer in year 2022. A view on T-shirts over a broad price range, with- and without claimed functional properties and eco labels is given. Additional to a view on price and marketing features, also the material composition and functional properties are investigated and reported. T-shirts with functional properties can be even found in the low-cost segment. However, by marketing using a combination of functional materials, eco labels and the statement "Made in Europe" T-shirts can be sold for reasonable higher prices.*

Keywords: eco label, UV protection, flame retardant, sport textile.

MAJICE – PREGLED I KOMENTARI CENOVNOG, FUNKCIONALNOG MATERIJALA I EVROPSKE PROIZVODNJE

Apstrakt: *Majica je verovatno najkorišćeniji i najsvestraniji komad tkanine. Sa ovom pozadinom, rad daje pregled različitih tipova majica koje se nude na nemačkom tržištu tokom proleća i leta 2022. godine. Pogled na majice u širokom rasponu cena, sa i bez zahtevanih funkcionalnih svojstava i daju se eko oznake. Pored pogleda na cene i marketinške karakteristike, takođe se istražuje i izveštava sastav materijala i funkcionalna svojstva. Majice sa funkcionalnim svojstvima mogu se naći čak iu jeftinom segmentu. Međutim, marketinškim korišćenjem kombinacije funkcionalnih materijala, eko etiketa i majica sa natpisom „Made in Europe" mogu se prodavati po razumno višim cenama.*

Ključne reči: eko oznaka, UV zaštita, usporivač plamena, sportski tekstil.

1. INTRODUCTION

There is probable no piece of clothing which is more distributed and more often used than a T-shirt. T-shirts are available in different styles, colors and prints [1, 2]. The price range for a single T-shirt sold in Germany (year 2022) is very broad with 3 Euro up to 300 Euro or more. This price range can be in a certain way explained by the used fiber materials. However, a significant factor is as well branding. Also, T-shirts with special functional properties are offered, as e.g. thermal comfort, anti-sweat, antimicrobial, deodorizing, UV-protective or flame-retardant [1, 3, 4]. A new technological trend is the combination of electronic devices with T-shirts for monitoring of human health parameters [5, 6]. In fact, different strategies can be identified to promote the selling of T-shirts and realize advanced prices. As mentioned, there are the fiber material or a promoted functional property. Information on sustainable aspects for material and ecolabels can be used for marketing. In some cases, a production "Made in Europe" is used as positive argument for promoting a

T-shirt. By this issue, the textile production in Eastern Europe can gain a chance for promotion and an advantage compared to the textile production in Far East. With this background the current study is dedicated to give a view on a selection of seven typical T-shirt products offered in Germany during the year 2022. Some material properties and, composition are presented as measurement results as basis for discussion of material properties. Most of these T-shirts are promoted with a special functional property, so especially this functional property is discussed with a comparison of the price range. A market price comparison is done. It should be remarked that the reported prices are related to spring/summer 2022. In year 2022, the general inflation in Germany reaches values around 10%. Basic food products (like wheat flour, cooking oil or noodles) increases in price even for 100% or more [7, 8]. However, till end of 2022 no significant increase in price for basic textiles are identified. Additional to the determination of some material properties one aim of the current paper is the discussion on the possible price range for a T-shirt under respect of fiber material, functionality, sustainability and region of production. Of course, there can be only a limited overview covering not all aspects and types of T-shirts, due to the broad field of products available on the market.

2.TEXTILE MATERIALS AND ANALYTICAL METHODS

2.1. Investigated T-shirt products

Seven different T-shirt products are selected as example for further discussion and are investigated by different spectroscopic and microscopic methods. An overview on these T-shirt materials together with further information is given in Table 1. The price range of these products is in the range from 3.5 to 72 Euro per piece. Information according to country of production, eco label and functional properties are recorded in Table 1. These data are taken from supplier information giving together with the T-shirt. It is not obligatory in Germany to mention the country of origin for textile products. For reported T-shirts, the countries of production are from Far East and Eastern Europe. As functional properties UV-protection is claimed for four T-shirts, while for one shirt flame retardant properties are claimed.

Sample No.1 is in the comparison the cheapest product and is supplied by the German textile discounter KIK. It is a white pure cotton material made in Bangladesh without any eco label or claimed functional property. Sample No.2 is in this selection the most expensive T-shirt and is offered with the brand UVEX standing for different innovative and functional products as goggles, helmets or sunglasses [9, 10]. In contrast, for this T-shirt no special functional property is claimed but for indication of sustainability an Eco label (Cradle to Cradle Gold) is used [11]. The production of this T-shirt is done in North-Macedonia but this fact is not especially mentioned for marketing reason. The samples 3 to 5 are supplied by the company iQ-UV which related their products especially on the protection against UV-light. By this UV-light protection a certain prevention against sunburn, skin-cancer and skin ageing can be reached [12-16]. Additional, to this main functional property, two Eco labels (OekoTex100 and Econyl) are used as marketing tools. The Econyl

Table 1: Overview on discussed T-shirt example materials based on the information given by the suppliers together with their product.

Sample no.	Supplier	Material and coloration	Coloration	Price per piece [Euro]	Producer country	Eco label	Functional property
1	KIK – German discounter	Cotton	white	3.49	Bangladesh	None	No special functionality claimed
2	UVEX	98% cotton; 2% elastane	Light grey	71.99	North Macedonia	Cradle-to-cradle gold	No special functionality claimed
3	iQ-UV	64% PET(recycled), 36% Tencel	white	44.00	Poland	Oeko-Tex100	UV protective
4	iQ-UV	64% PET(recycled), 36% Tencel	orange	44.00	Poland	Oeko-Tex100	UV protective
5	iQ-UV	86% polyamide, 14% elastane	blue	40.00	Poland	Oeko-Tex100; Econyl	UV protective
6	Decathlon	Polyester	green	9.99	China	None	UV protective
7	Blaklader Workwear	60% modacryl, 39% cotton, 1% other fiber	black	68.07	Myanmar	None	Flame protective

label signs products made from recycled nylon fibers [17]. Also, the production "Made in Europe" (Poland) is clearly mentioned as positive feature for these T-shirts. The samples 6 and 7 are produced in Far East and are especially promoted related to their functional properties. The sample 6 stands for UV protection and is supplied by Decathlon aiming the sports sector. Sample 7 is a flame protective textile offered as workwear and is by this significantly different from the samples 1 to 6 which are mainly offered for private customers.

2.2. Analytical methods

The fabric topography is investigated using scanning electron microscopy (SEM). For these investigations a Tabletop TM3000 microscope (Hitachi, Japan)

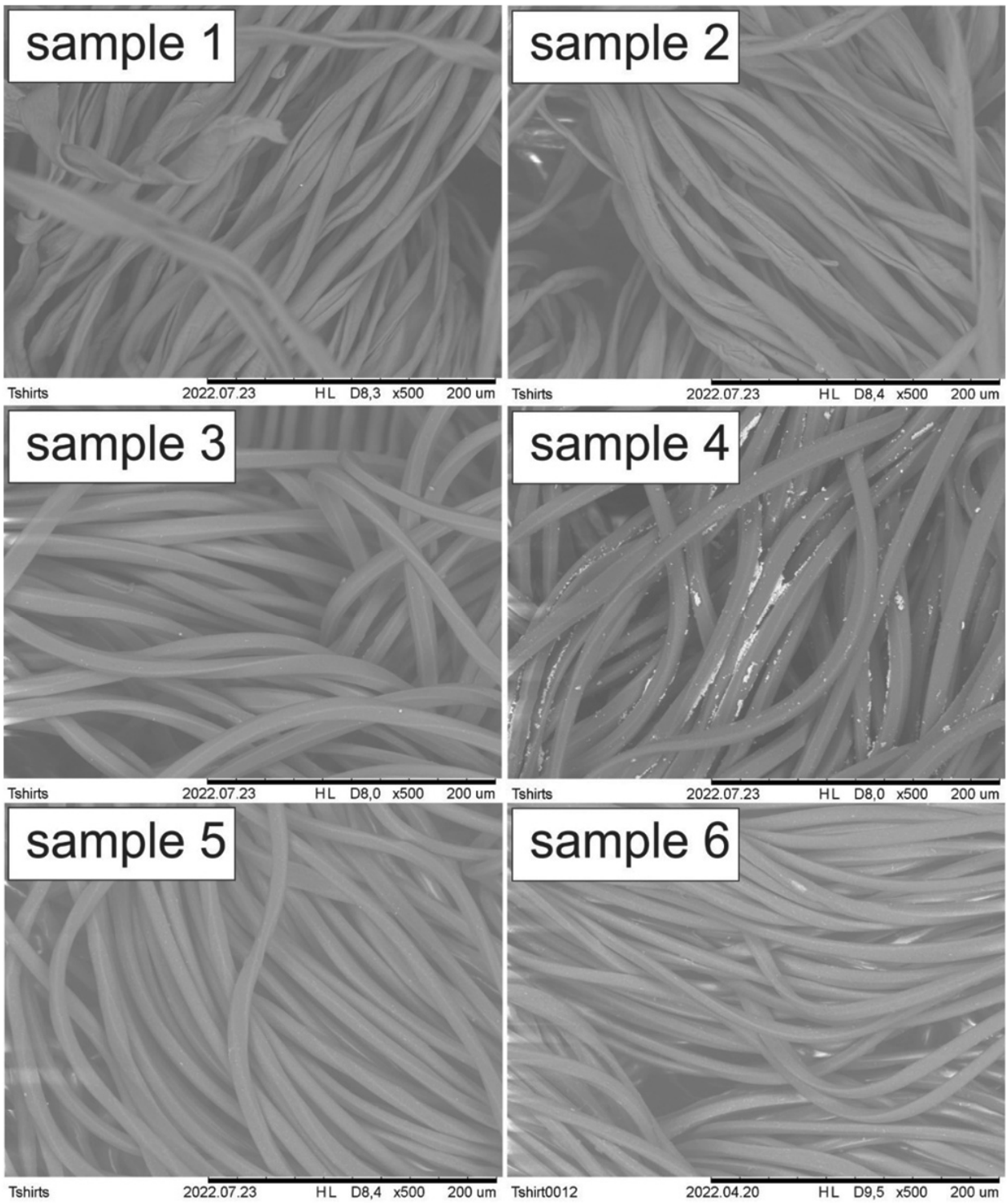

Figure 1: Microscopic images (SEM) – overview for the samples 1 to 6.

is used. This electron microscope is further equipped with an EDS unit (Electron Dispersive Spectroscopy) Quantax 70 supplied by Bruker. By using this EDS unit, the presence and concentration of chemical elements on the fabric surface can be determined. However, the chemical element hydrogen cannot be detected by EDS. The sensitivity of the EDS methods can differ strongly for different chemical elements. Usually chemical elements with higher atomic mass exhibit stronger signals in the EDS spectrum [18, 19]. Chemical elements with concentration below 0.1 wt-% cannot be identified clearly. The optical transmission of textile samples is measured using a photospectrometer UV2600 supplied by Shimadzu (Japan). These spectroscopic measurements are done in arrangement of diffusive transmission for a spectral range form 220 nm to 1400 nm. For measurement of diffusive transmitted light an integrating sphere is used. These measurements cover beside the UV- and visible spectral range also the range of near infrared light till 1400 nm. From spectral data of UV transmission, the UPF factor (UV protection factor) is calculated. Fluorescence emission and excitation spectra are recorded using a fluorescence spectrometer RF-6000 (Shimadzu, Japan).

3. MATERIAL PROPERTIES AND DISCUSSION

3.1. Textile surface and composition

Microscopic images for the samples 1 to 6 are given in Figure 1. The cotton fiber structure can be clearly identified for the samples 1 and 2. The typical shape of synthetic fibers is identified for the samples 3 to 6. For this, the supplier information related to the used fiber materials are proofed. Additional, for sample 4 residues on and between the fibers are recorded. These residues are probable related to the presence of titaniumdioxide TiO_2, which can be used as UV-protective agent [16, 20, 21].

Figure 2 summarizes the EDS-spectra for the samples 1 to 6. The detected chemical elements on the fabric surface are indicated at the related signals in the EDS-spectra. Also, given are the determined concentration of chemical elements in weight-percentage (wt-%). Samples 1 and 2 exhibit a relation of carbon and oxygen which is typical for a cellulosic fiber as cotton [19]. Additional, sample 2 contains small amounts of magnesium, silicon and chlorine. The occurrence of these elements is probable caused by dyeing and washing procedures. The EDS spectra of samples 3, 4 and 6 are dominated by the signals for carbon and oxygen in a ratio which is typical for the polyester fiber material PET. Additional, titanium is here determined in concentration from 0.5 to 2.2 wt-%. This titanium is probable related to the presence of titaniumdioxide TiO_2. TiO_2 is an effective UV protective material [22, 23]. TiO_2 is also an excellent white pigment and often added to synthetic fibers and filaments during fiber production to reach matting effects [24, 25]. The EDS-spectrum of sample 5, exhibits also a small signal which is dedicated to the presence of nitrogen. The sensitivity of the EDS method for nitrogen is low, so even with a significant nitrogen concentration of 14 wt-% the related EDS signal is small [19]. The presence of nitrogen in this amount is explained by the polyamide structure of the Nylon fibers from sample 5. The determined titanium is probable as well related to TiO_2 as UV-absorber and white pigment. The small content of Sulphur can be explained as result from dyeing processes, because many dyes contain sulphur as part of a sulfonate group or reactive group [26-29]

Microscopic images and EDS investigations for sample 7 are depicted in Figures 3 and 4. This separate presentation is done, because of the presence of high-performance fibers in sample 7. Sample 7 contain cotton and chlorinated acrylic fibers, which are related to inherent flame retardant properties due to the chlorine content [30, 31]. In the SEM images the modacrylic fibers are clearly identified due to their brighter appearance (Figure 3). A performed EDS mapping proofs the presence of chlorine in the brighter fibers (Figure 4). The EDS spectrum of sample 7 exhibits a dominant signal to the presence of chlorine. The sensitivity of the EDS method to the element chlorine is strong. For this, the content of around 10 wt-% chlorine leads to the same EDS signal intensity as 50 wt-% carbon in the same sample. Additional, small amounts of sulphur and antimony are detected. The presence of sulphur can be explained by the presence of sulfonate groups as part of the chemical structure of anionic acrylic fibers [28]. The presence of antimony is in a certain way surprising but could be explained by the application of antimony oxide Sb_2O_3 pigments [31]. Sb_2O_3 pigments are known to enhance the flame retardant action of halogenated flame retardants [31]. By view on the used flame retardant high-performance fibers and the application of antimony oxide pigments, the relatively high price of the T-shirt sample 7 can be justified from material point of view.

3.2. UV protective properties and transmission for infrared light

The UV protective properties of the T-shirt samples are determined by measurement of the diffusive transmission for UV-light (Figures 5 and 6). From these

transmission values also the UPF-factors are calculated and presented in Table 2. In Figure 5, the complete determined transmission spectra in a range from 220 nm to 1400 nm are presented. This presentation covers the UV range, the visible range and the range for near infrared light (IR light). To support a more detailed view on the UV range, Figure 6 presents the spectral area from 280 nm to 400 nm, which is especially relevant for the calculation of the UPF factor. The visible range of the transmission spectra is determined by the fabric coloration. The white samples 1 and 3 exhibit a constantly high transmission for visible light in the range from 27 to 30%. The black sample 7 exhibits nearly 0% transmission over the complete visible range of light, due to a total absorption of visible light. The other samples show transmission for visible light according to their absorption of light related to their coloration. For infrared light (IR range) most samples exhibit transmission of around 30%. Remarkable is that sample 6 exhibits a lower IR transmission in the range of 22 to 25% (Table 2), which is a significant decrease but probable not enough to promote a certain kind of IR protective property. The use of pearlescent pigments as coating additives can be used to decrease the transmission of IR light further [21].

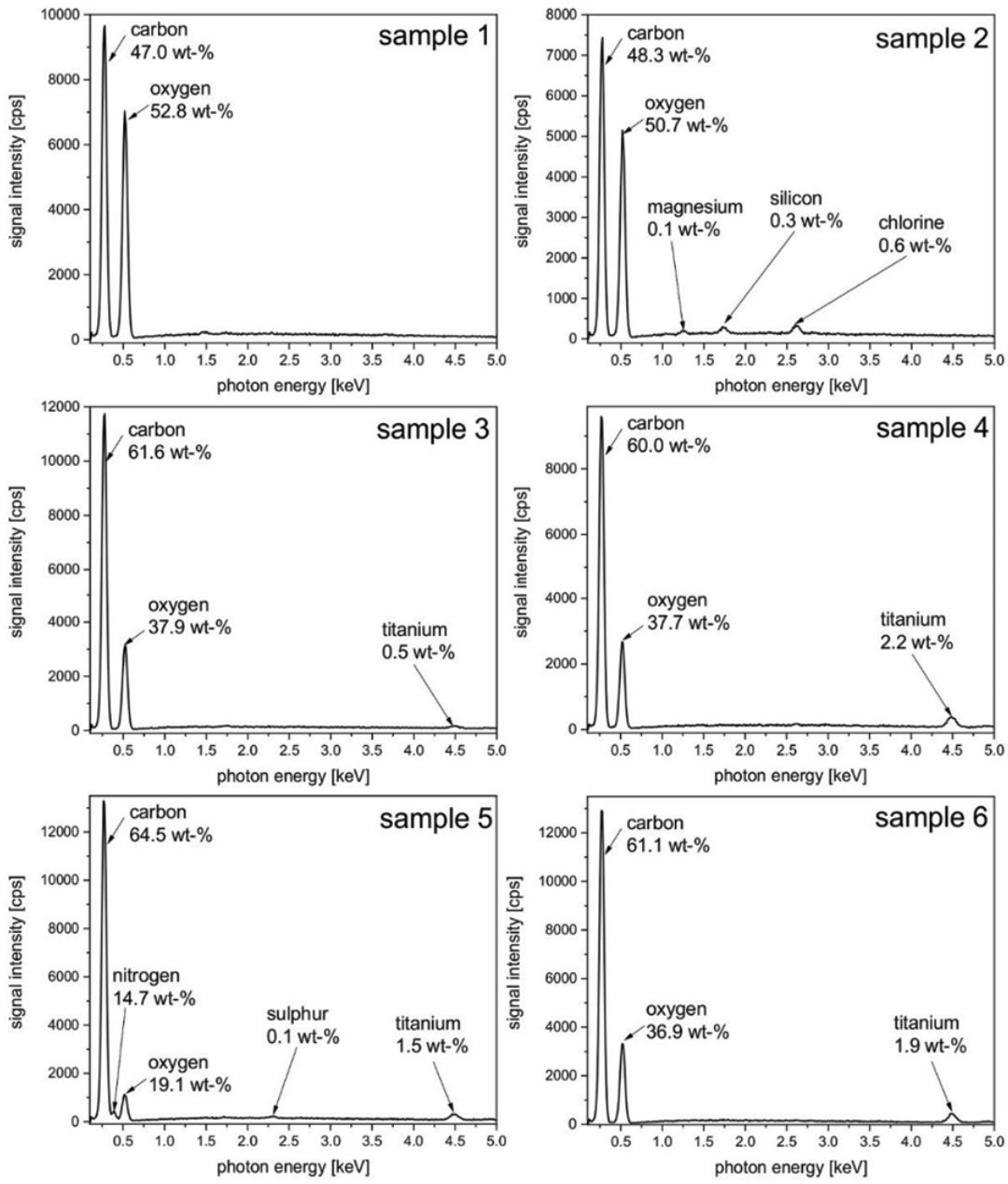

Figure 2: EDS spectra – overview on the samples 1 to 6. The amount of detected chemical elements are given in the EDS spectrum. Chemical elements with detected concentration less than 0.1 wt-% are not mentioned.

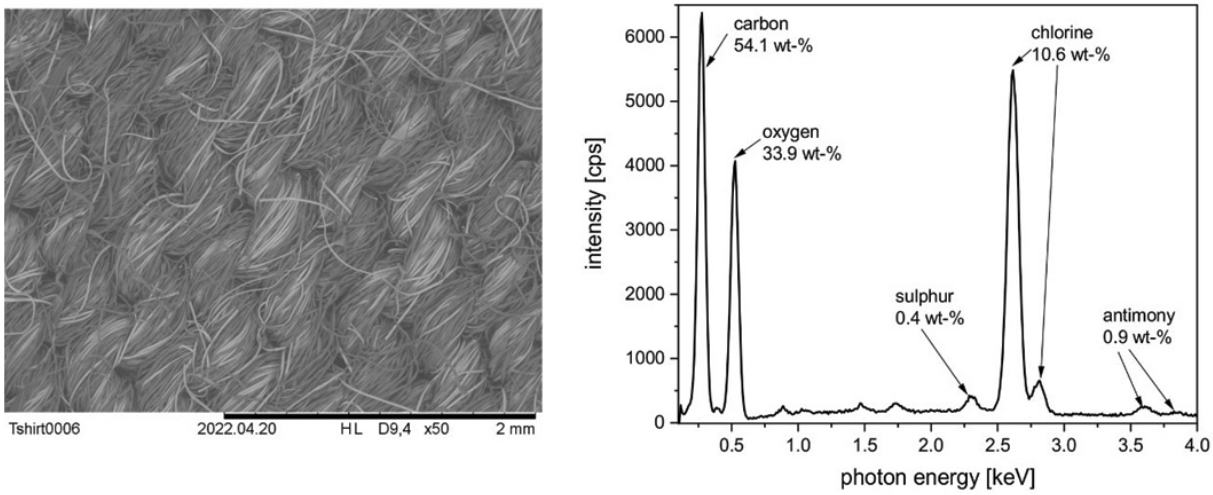

Figure 3: Flame protective T-shirt (sample 7) – microscopic image (SEM) and EDS spectrum of related sample. The amount of detected chemical elements are given in the EDS spectrum. Chemical elements with concentration less than 0.1 wt-% are not mentioned.

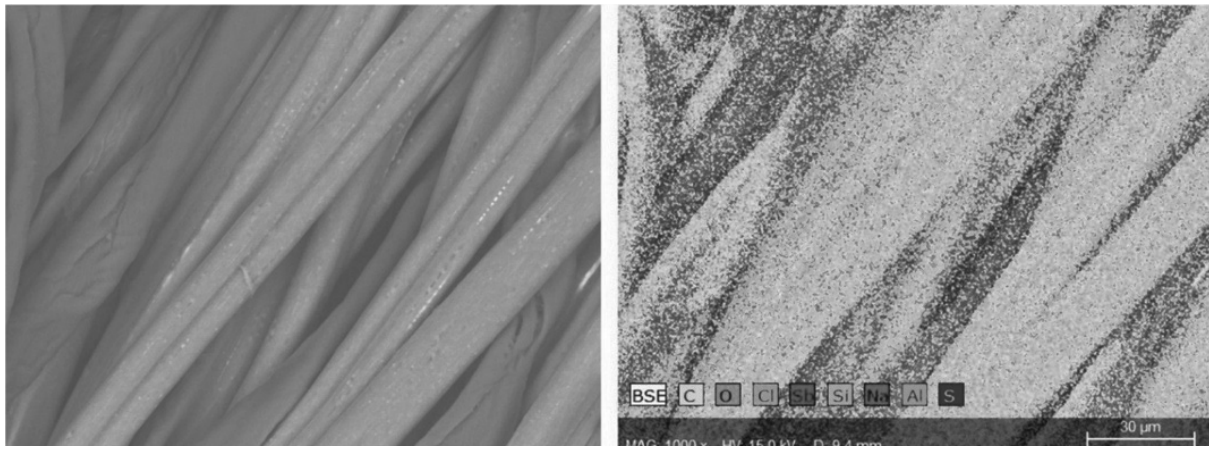

Figure 4: Flame protective T-shirt (sample 7) – microscopic image in higher magnification (SEM) and EDS mapping at the same sample area. The green areas indicating the dominant presence of the element chlorine.

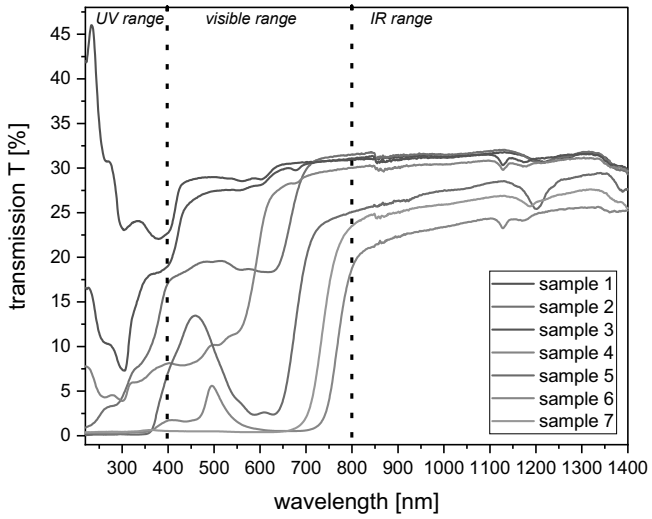

Figure 5: Optical transmission spectra of different T-shirt samples over complete measured spectral range from UV to near IR. Shown is the diffusive transmission.

By view on the UV transmission spectra, it is clear that the white T-shirt sample 1 offers no significant UV protection with quite high transmission values between 25% to 30% (Figure 6). This high transmission corresponds to a low UPF value of only 4.3 (Table 2). The samples 5 to 7 exhibits excellent UV protective properties (Figure 4 and Table 2). For T-shirt sample 7, this functional property is not especially promoted but can be explained by the applied black dyestuff which absorbs also UV-light [32]. Surprising are the high transmission values for sample 3 and 4 and according their only moderate UPF values, because for these samples the UV protection is promoted as functional property.

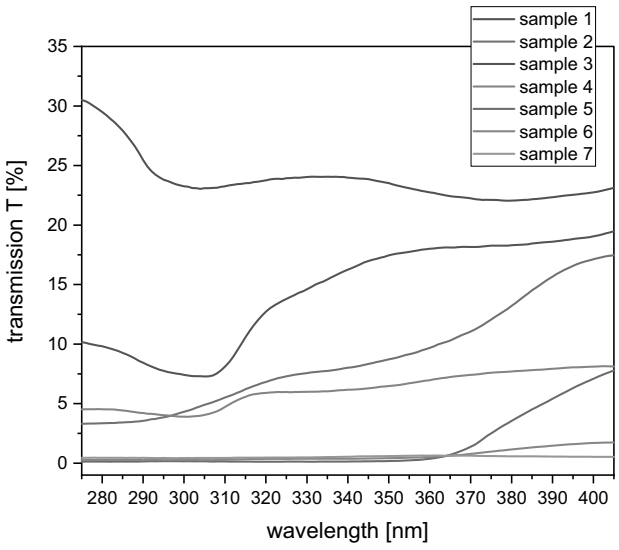

Figure 6: Optical transmission spectra of different T-shirt samples for the spectral area relevant for UV protective applications. Shown is the diffusive transmission.

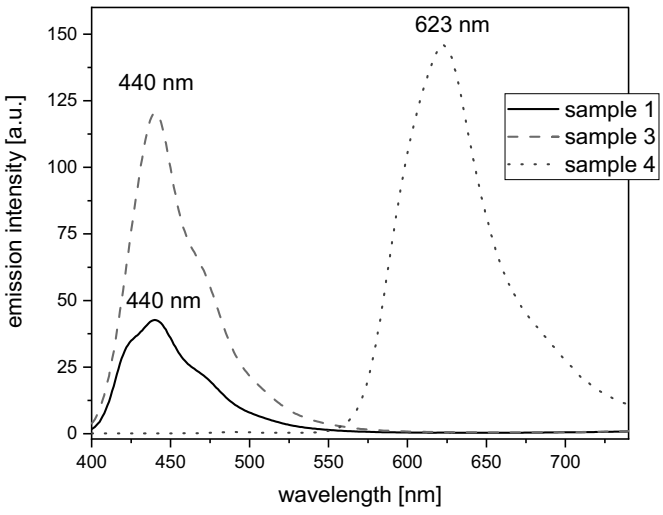

Figure 7: Fluorescence emission spectra of different T-shirt samples. The excitation is done with UV light of 380 nm.

Table 2: Overview on UPF factors and transmission values for UV light and IR light at distinct wavelengths.

Sample no.	T at 280 nm [%]	T at 380 nm [%]	UPF factor	T at 850 nm [%]	T at 1350 nm [%]
1	29.5	22.0	4.3	31.1	31.2
2	3.4	13.2	17.2	31.5	31.2
3	9.8	18.3	10.5	31.0	30.8
4	4.5	7.7	20.6	30.1	30.5
5	0.1	3.6	459.4	25.8	29.3
6	0.3	1.1	291.8	21.3	25.2
7	0.4	0.6	227.8	24.7	27.2

This measurement result can be explained by fluorescence properties and the measurement arrangement for recording the UV transmission spectra. The samples 1, 3 and 4 exhibit fluorescent properties, which can be shown in related fluorescence emission spectra (Figure 7). Samples 1 and 3 have a white appearance and a fluorescence emission with a maximum at 440 nm. This kind of emission spectra with fluorescent blue light is typical for the application of optical brightener leading to a special bright and white appearance of a fabric [33]. Such optical brighteners absorb also UV-light. The type of absorbed UV light due to fluorescent properties can be seen by view on fluorescent excitation spectra (Figure 8). For this, optical brighteners can be also used as effective UV absorbing materials to introduce UV protective properties to clothes [33]. However, this UV absorption by optical brightener is accompanied with emission of visible light, so misleading measurement results may occur during recording a UV transmission spectrum, if a detector set-up is used which cannot distinguish between UV and visible light. Sample 4 with orange coloration exhibits fluorescence emission with a maximum at 623 nm, which is in accordance to the orange coloration of this sample (Figure 7). Here, the fluorescence excitation is especially high for the UV range 300 to 400 nm, which is the important spectral region to gain UV protective properties.

3.3. Market price comparison

The market price comparison for the seven samples is done with examples for three different categories stated as low, medium or high price segment category (Figure 9). Examples are taken from func-

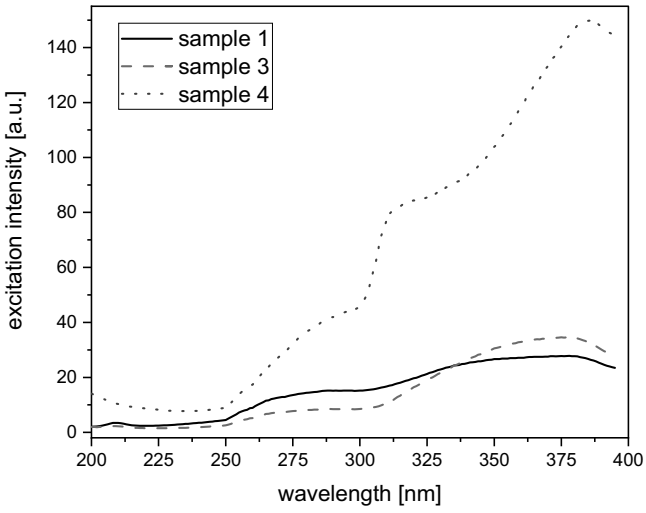

Figure 8: Fluorescence excitation spectra of different T-shirt samples. The excitation is recorded for an emission at 420 nm for the samples 1 and 3. For sample 4, the excitation is recorded for an emission at 620 nm.

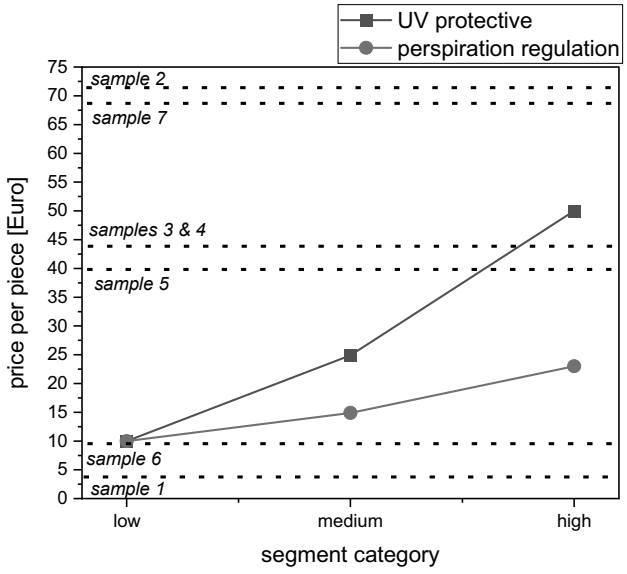

Figure 9: Price comparison of different product examples – T-shirts from sport segments from different price segment categories. Given are examples promoting the functional properties UV protective and perspiration regulation. The dotted lines indicate the prices of the samples 1 to 7.

tional sport T-shirts with the promoted functions "perspiration regulation" and "UV-protective". For the low price segment, the brand Decathlon is chosen as example, which is offering in the segment functional T-shirt products in the price range from around 4 to 90 Euro [34, 35]. A typical product example from Decathlon with UV-protection and perspiration regulation is already given with sample 6 and as well mentioned in Figure 9. As brand example for the medium price segment the brand Intersport is chosen. Functional T-shirts are available at Intersport in the price range from around 10 to 120 Euro [36-38]. Here, as comparative example for perspiration regulation a shirt for 15 Euro and for UV-protection a shirt for 25 Euro is chosen. The example for the high price segment is given with the sport brand Adidas, offering functional T-shirts in the range from around 18 to 300 Euro [39, 40]. For the current comparison, from this brand a UV protective T-shirt for 50 Euro is selected and a T-shirt with perspiration regulation for 20 Euro.

The T-shirts 3, 4 and 5 are in the price range between medium and high segment category. Even if the brand iQ-UV is less known than Intersport or Adidas, here the concept of crosslinking the functional property, sustainability and "Made in Europe" is sufficient to realize the aimed price range. The high price for the T-shirt sample 7 is probable dedicated to the use of high-performance fibers and the work-wear function of flame retardance. Surprising is the highest price for sample 2 even without promoting a special functional property. For sample 2 only the eco label is presented. Here, probable the brand UVEX is the main argument for realization of the price. In any case it can be stated that functional T-shirts are available for reasonable low price. However, in this price range a labeling for sustainability obviously cannot be supported. Nevertheless, from textile material point of view no disadvantages can be remarked.

4. CONCLUSIONS

In an overview seven T-shirts offered in year 2022 in Germany are presented and compared. The type of fiber material, promoted functional properties, eco labelling and country of production vary in broad range. A correlation between price and material properties is not obvious for all parameters. However, it can be stated that promoting a functional property together with ecolabelling and production in Europe can be used for realization of moderate to high prices even for less know fashion brands.

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All product and company names mentioned in this article may be trademarks of their respected owners, even without labeling. No funding was supported for this article. The authors claim no financial interest or conflict to the mentioned products or companies.

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