Identification and Quantitative Determination of Virgin and Recycled Cashmere: a Near Infrared Spectroscopy Study

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Abstract

Cashmere plays an important role in luxury fashion due to its characteristic of fineness, warmth and softness. In frame of "green economy", many companies start to produce and market recycled cashmere textiles. Recycled cashmere derives from post-factory and post-consumer waste. The mechanical action involved in recycling cashmere causes several damages of fibers affecting their morphological and mechanical properties. In order to safeguard the consumers and the companies to possible adulteration, a correct identification of fibers is required. NIR spectroscopy was applied to analyze and distinguish virgin and recycled cashmere fibers. Since no significant differences can be seen in the recorded spectra, the principal component analysis (PCA) combined with the soft independent modelling class analogies (SIMCA) method allows the classification of fibers in two distinct classes leading to have a sure identification of recycled and virgin cashmere. A calibration curve was also performed in order to quantify recycled cashmere fibers in a blend with virgin ones. The interclass distance in SIMCA method was found to be 249,77, whereas results from quantitative calibration shows a standard error of prediction (SEP) value of 5,8 % w/w (for a mean value of 50 % w/w). Microscopy analysis was also carried out to confirm the origin of recycled cashmere. These preliminary results confirmed that the NIR coupled with chemometric methods might be a useful tool for a rapid screening of recycled cashmere fibers and their raw quantification in a blend.

Keywords Recycling, cashmere fiber, NIR, chemometric analysis, quantitative analysis, SIMCA modelling, PCA analysis

Introduction

Cashmere is regarded as a luxury and rare animal fiber [1]. It is characterized by fineness, softness, and warmth and it derives from the fine dehaired fiber of goats undercoat [2]. Cashmere fibers are used to make a large variety of woolen products such as scarves, pull-overs and cardigans and it also used as raw materials for high value adding by the textile industries [3]. Thus, cashmere has a high natural value related in part for its intrinsic properties and in part for the tradition associate with its production [4]. At the present, some European countries produce and import cashmere for the production of luxury garments that leads to a multi-billion-dollar global trade [5]. Globally, most of the world cashmere production belongs to Asian countries, such as China, Mongolia, Afghanistan, Kazakhstan, Iran and India which are able to produce different grade of cashmere. Relatively small quantities of cashmere are also produced by Britain, Australia and New Zealand [6]. Anyway, the global production of cashmere is negligible respect to other products in whole industrial textile, but it is a luxury component used by major fashion brands [4]. Due to its high value and in frame of "circular economy", many brands start to produce and sell recycled cashmere products. "Recycled cashmere" is a term used to indicate fibers that derives from post-factory scraps and post-consumer textile wastes. Recycled cashmere product is a relatively evolving concept, and in literature little attention is paid on it, due to the fact that it is questionable to recycle cashmere fiber to produce luxury products without affecting the quality [7]. This kind of fibers have a lower quality than the virgin ones due to the mechanical recycling processes that they have been undergone. Current U.S. legislation requires to indicate the presence of recycled fibers in textile products, but false declaration and adulteration of virgin cashmere manufactures are not uncommon [4]. Thus, the identification and recognition of virgin and recycled cashmere fibers is becoming fundamental.

Throughout the literature, the most common methods used for distinguishing fine animal fibers are light microscopy (LM), scanning electron microscopy (SEM), MALDI-TOF and DNA analysis [8]–[10]. Light and SEM microscopies are

the most well-assessed methods due to their low cost and high efficiency. However, the accuracy of these techniques depends mainly on the skills of the operator.

MALDI-TOF spectroscopy is a biochemical method for fiber identification of closely related species after an enzyme digestion [11]. In this case, peptide mass finger printing (PMF) has been successfully used to identify the species origin. Regarding the DNA analysis, it is based on the isolation of the DNA in cells of different kind of fibers. The DNA profiling can identify fibers of different species if a suitable and unique DNA probe can be recognized [12]. However, this technique has many drawbacks, for instance, it is difficult to differentiate DNA of closely species, it requires time for setting the instrumentation and the analysis of DNA can be affected by different extraction yields [13]. The proposed methods, which are able to discriminate from different animal hair origin, are not suitable in the case of virgin and recycled cashmere identification.

Recently, a fast, efficient and objective detection technology has become an imperative scientific and a technological demand. NIR technology has made significant progresses in many fields, such as food analysis [14], agrochemical quality control [15] and in cognitive neuroscience research [16]. Actually, NIR technology has found out different applications in quality control in order to protect the consumer from possible products adulteration. For instance, Prieto *et al.* used the NIR and the multivariate analysis for quantitative and qualitative purposes in meat sector, whereas Schmutzler and co-workers employ the NIR for the effective quality control of apples [17], [18]. Currently, NIR spectroscopy is becoming a routine analytical technique in textile field, and actually in fiber recognition. The success of the NIR spectroscopy is mainly due to the non-destructive detection and rapidity. NIR is a part of electromagnetic spectrum ranging from 13000 to 4000 cm^{-1} [19]. All the absorption bands in this region are the results of overtones and combinations originating in the fundamental mid-range (4000-600 cm^{-1}) infrared region of the spectrum. The bonds involved are usually R-H (C-H, O-H, N-H, S-H) [18]. After a calibration based on the chemometric methods, the NIR allows a simple and fast test for samples. Generally, in the NIR approach, the principal component analysis (PCA) is performed. In PCA, multiple original variables are replaced with a lower number of variables in order to eliminate the overlap spectroscopy data without losing the main information. Actually, to characterize many raw materials or to control textile products and processes, the PCA is coupled with soft independent modelling class analogies (SIMCA). The SIMCA method is based on modelling each class by a separate model [20]. The scope of this statistical tool is to reduce dimensionality of the multivariate data set and to find classes of samples in data set [21]. With the help of SIMCA model, many research groups successfully carried out the correct identification and classification of samples in the field of biology, chemistry and medicine [21]–[23]. Using NIR spectroscopy, it is also possible to find quantitative relationships between the NIR spectra and some characteristics of the samples, in general obtained by expensive or time-consuming tests. Those expensive measurements can be predicted rapidly and with high accuracy using a NIR calibration. The multivariate regression methods, most frequently used in NIR spectroscopy, are principal component regression (PCR) and partial least-squares (PLS) regression.

NIR spectroscopy can be applied to various kinds of materials such as bulk, thin or thick polymers, tablets, human bodies and to various fields, including polymer science, on-line monitoring, inorganic material research, medical diagnosis, and NIR imaging [24]–[26]. NIR spectroscopy is particularly powerful in non-invasive, non-destructive and *in situ* analysis. In the textile field NIR spectroscopy in combination with chemometric methods is an emerging quantitative and qualitative technique for identification of textiles, adulteration control, textile wastes sorting for recycling, moisture measurements, process control, forensic and cultural heritage textile analyses [7], [27], [28].

For instance, Wu *et al.* [29] proposed a quick and non-destructive method to identify some textile fibers as sorting technique for textile wastes recycling. A fast and accurate identification model was built using SIMCA method and a prediction accuracy of 100% for polyester, polyamide, acrylic, silk and wool was found. Ishfaq [30] discusses the availability of NIR in recycling textile waste concluding that it will be possible a large commercial scale for sorting textile automatically using NIR equipment. Lately, Zoccola *et al.*, in field of fine animal fibers, have successfully used the NIR spectroscopy to classify and discriminate wool, cashmere, yak and angora fibers in raw state and quantify wool and cashmere in blends, concluding that NIR spectroscopy coupled with multivariate analysis can be used as a tool for a first and rapid screening of unknown animal fiber samples in the raw or combed sliver state and useful to obtain a fast and coarse estimate of the amount of wool and cashmere fibers in a blend [8]. Concerning the cashmere, Wu *et al.* applied the NIR spectroscopy combined with PCA to build an analysis model to discriminate 5 varieties of cashmere [31]. On the field of recycled materials, Xin *et al.* developed a NIR spectroscopic method employing partial least squares discriminate analysis able to distinguish between tissue papers made from virgin and recycled fibers in blends [32].

The aim of this work is the development of a novel, fast quantitative analysis for the identification of virgin and recycled cashmere that might be important for developing portable or in-line devices for testing in real-time the quality or the

possible adulteration of commercial cashmere textiles. Herein, it is reported the qualitative and quantitative identification of virgin and recycled cashmere fibers, by using NIR technology.

Materials and methods

In this study, 74 different virgin and recycled cashmere samples in the raw or combed states were analyzed. The recycled cashmeres were provided by different textile companies in Biella, whereas for the analysis of the virgin fibers, samples from CCMI (Camel Hair Manufacturers Institute) were used.

- Moisture uptake

Moisture uptake versus time of virgin and recycled cashmere samples, previously dried to constant mass at 105 °C, was determined by weighting samples over time in a conditioned room with standard conditions (20 °C, 65% RH).

- Sample preparation

Before NIR spectra acquisition, all the recycled and virgin cashmere samples were dried in an oven at 105° C until constant weight and then conditioned for 24 h under standard atmosphere (20 °C, 65% R.H.). For the quantitative analysis, 18 blends were prepared. More in detail, known amounts of recycled and virgin cashmere were mixed by hand cardes in order to obtain 18 blends with a quantity of recycled cashmere ranging from 0% to 100%.

- NIR spectra acquisition

An FT-NIR spectrometer (PerkinElmer-Spectrum IdentiCheck) equipped with a reflectance sphere was used for the analysis of the samples. For each sample, 32 scans were recorded between 10000 and 3700 cm^{-1} with a resolution of 4 cm^{-1}. All the spectra were collected using 1g of cashmere sample.

- Classification of the sample

For the classification of the two different classes of cashmere, the SIMCA method was used. In this work, 54 samples (27 of virgin cashmere and 27 of recycled cashmere) were applied to build the model, and other 20 samples (10 of virgin and 10 of recycled cashmere) was used to test the reliability of the model. The number of principal component selected was two. The method was built and calibrated using the PCR algorithm. The number of evaluated components are 2. The spectra were processed in the range of 7500-3700 cm^{-1} in order to avoid interferences caused by the pigmentation of the cashmere. Spectral pre-processing was performed to eliminate noise and scattering. 8 cm^{-1} resolution, standard normal variate transformation (SNV) algorithms followed by Savitzky-Golay smoothing (5 smoothing points) was applied to correct the baseline shift and multiplicative scatter effects and ~~the autoscaling function were also applied~~. In order to provide a sample selection for the calibration and validation set as representative as possible and to ensure uniformity of dataset, the X and Y distances were taken into account simultaneously, by applying the Kennard–Stone (KS) algorithm. Predictive capabilities of this calibration model and its validation was evaluated by using several statistical parameters, i.e. the coefficient of determination (R^2), standard error of estimate (SEE) and standard error of prediction (SEP)

In SIMCA, the PCA was performed for each class. The PCA is a useful chemometric method for spectral data compression and information extraction [33]. It allows to describe with a small number of principal components (PC) the most important information contained in a spectrum. Thus, SIMCA model creates a multidimensional box for the two classes and it allows to classify an unknown sample in accordance with its fitting to one of the two classes constructed [7].

- Quantitative analysis

The 18 samples of virgin and recycled blend fibers were obtained as previously described and used for the calibration. The weight percentage of virgin cashmere in each sample was associated with the respective spectrum. The data were processed by means of Spectrum Quant+ (PerkinElmer) software package and the PCR algorithm were used for the calibration in the range of spectra acquisition 7500-3700 cm^{-1}. The principal statistics used to assess the quality of the results were the standard error of prediction (SEP), which is the magnitude of error expected when independent samples are predicted using the model, the standard error of estimate (SEE), and the coefficient of determination of the calibration (R^2).

- SEM analysis

The morphological investigation of the recycled and virgin cashmere was carried out by Zeiss EVO 10 SEM. SEM operated with an acceleration voltage of 15 kV, 50 pA probe and 20 mm working distance. Samples were mounted on aluminum stubs and coated with a gold layer 20-30 nm thick in argon, using an Emitech K 550 sputter coater with a current of 20 mA for 180 s.

- Light microscopy

The microscopic investigation was carried out on virgin and recycled cashmere with a DM-L Light Microscope (Leica) in the Transmitted Light mode. The specimens were prepared dripping some drops of glycerin onto the sample placed on a glass microscope slides.

Results

Virgin and recycled cashmere characterizations and spectral analysis

Virgin and recycled cashmere samples were examined with a scanning electron microscopy (SEM), in order to evaluate differences in morphology of fibers.
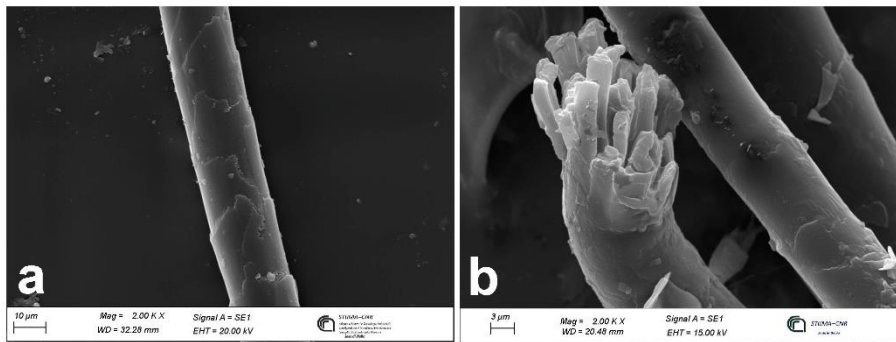
Figure 1: SEM analysis of virgin (a) and recycled (b) cashmere

Figure 1a shows the typical morphology of a virgin cashmere fiber [34]. Fiber has a cylindrical shape with an even diameter. The surface scale displays the typical overlapped patterns and the scales are relatively distant and smooth. The mean scale frequency is 6-7 per 100 μm and the thickness of the cuticle cells at the distal edge is less than 0.5 μm. In Figure 1b recycled cashmere fiber with typical breakings due to mechanical re-processing is shown and a typical partial cleavage (semi-rupture) called "brushes" is reported. The SEM analysis is often used for recycled animal fiber identification, but this method has some drawbacks due to the intrinsic subjectivity of the technique.

In this work, NIR spectroscopy analysis has been used as an objective method to identify recycled and virgin cashmere fibers. Since specific regions in the NIR spectra are sensitive to the concentration of water absorbed, the samples were dried and conditioned in order to evaluate possible differences in moisture uptake. The obtained results for virgin and recycled cashmere samples are listed in Table 1.

Time (h)	Water adsorbed by virgin cashmere (%)	Water adsorbed by recycled cashmere (%)
1	0	0
2	8.4	8.7
3	9.4	10.4
4	9.6	10.6
5	9.8	10.7
6	9.8	10.7
7	9.9	10.7
15	11.1	11.2
24	11.3	11.6

Table 1: Moisture uptake (%) by virgin and recycled cashmere recorded at different times

As shown in table 1, after 3 h, the recycled cashmere absorbed a higher amount of water than the virgin sample and this behavior can be related with the presence of breakages along the fibers that allows the diffusion of water molecules into the structure. Indeed, the disruption of hydrophobic external cuticle layer leads the recycled cashmere to be faster in water adsorption, but after 15 h, water absorption slightly increases for both the samples until the achievement of equilibrium conditions leading to the same moisture uptake. The initial differences in moisture absorption could be emphasized and exploited in NIR spectroscopy, but the equilibrium states are easier to manage in analytic conditions, which are more reproducible among laboratories, without affecting the speed and simplicity offered by NIR spectroscopy. For this reason, all samples were dried at 105°C until constant weight and then conditioned for 24 h before being analyzed.

The conditioned samples were analyzed using the NIR spectrophotometer. All the NIR spectra collected show similar patterns and for brevity, in Figure 2, one spectrum for a virgin cashmere sample (black solid line) and one for a recycled one (black dotted line) are reported. For both the samples, the peak positions and overall shape are very similar due to the same chemical composition. The shoulder at 7000 cm^{-1} is assigned to the first overtone of the O-H stretching vibration of the adsorbed water whereas the bands at 5200 cm^{-1} is related with the combination of O-H stretching and H-O-H bending vibration of water. The overtone at 5800 cm^{-1} is ascribed to C-H stretching of the protein side chains [8].
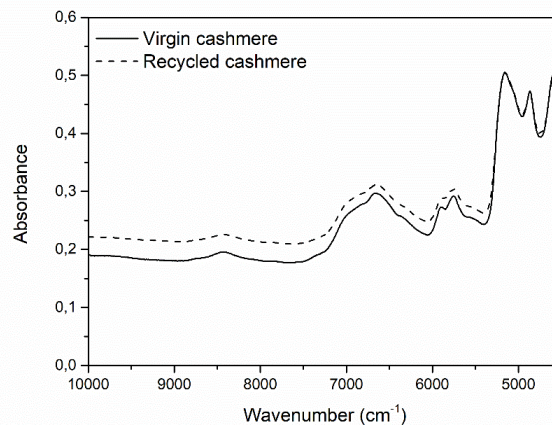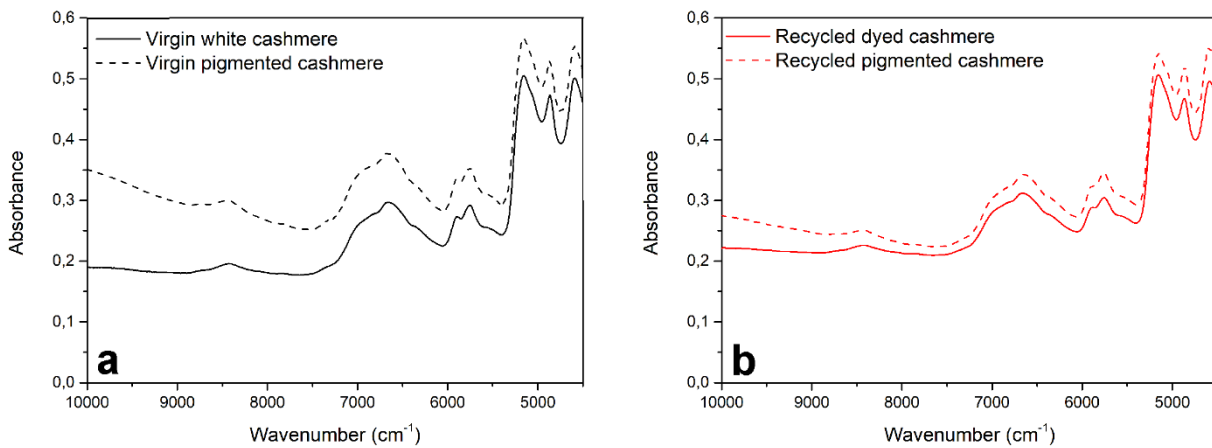

Figure 2: Virgin cashmere (black solid line) and recycled (black dotted line)

However, a significant discrepancy in the baseline absorption intensity can be observed. This spectral difference should be associated with the physical differences between the two kinds of fibers. These variations can be related with different physical characteristics, such as sample packing, surface roughness and fiber diameter and they cause the light scattering effect [31]. Another characteristic that alters the NIR spectra is the present of pigments in cashmere fibers. Indeed, cashmere is not only white, but it can be found in different shade of brown. These difference are mainly due to the presence of pigments, mainly, melanin. Thus, the virgin and the recycled cashmere fibers can be pigmented or not, but a visual comparison between the two kinds of cashmere is difficult because recycled samples are usually found out dyed in different colors. Since the presence of color used for dyeing cashmere does not affect the spectral baseline, the presence of pigments can be detected by NIR analysis [7] [35]. In Figure 3a the spectra of virgin (black solid line) and virgin pigmented cashmere (black dotted line) are reported, whereas in Figure 3b the spectra of recycled (black solid line) and recycled pigmented cashmere (red dotted line) are shown.

1

Figure 3: a) Spectra of virgin cashmere (black solid line) and virgin pigmented cashmere (red solid line); b) Spectra of recycled cashmere (black dotted line) and recycled pigmented cashmere (red dotted line)

As shown in Figure 3, due to the presence of pigments on the surface of the fibers, both the pigmented cashmere presents a heavy drift of the spectral baseline in wave region from 10000 to 7500 cm^{-1}.

The presence of pigments in the cashmere samples can be also evaluated using light microscopy, as shown in Figure 4:

8
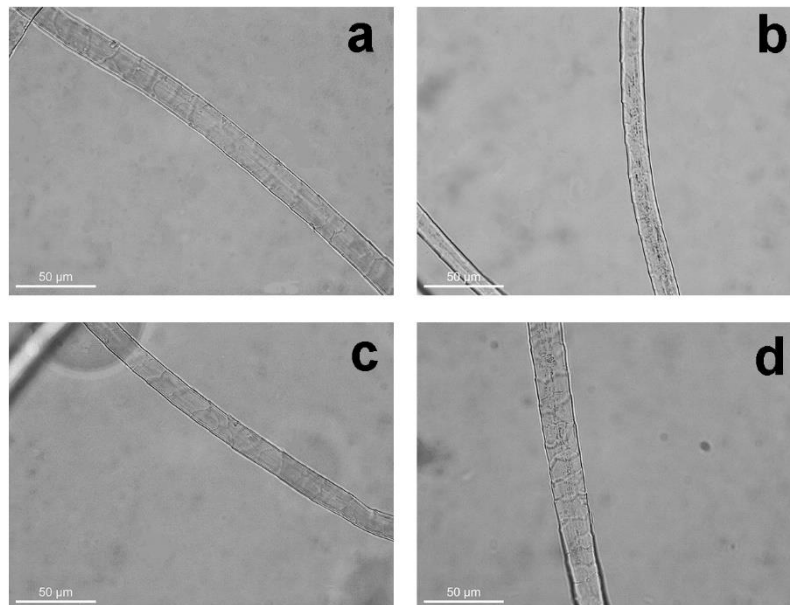
Figure 4: Light microscopy images of virgin cashmere (a), pigmented virgin cashmere (b), recycled cashmere (c) and recycled pigmented cashmere (d)

Figure 4a depicts a white virgin cashmere with typical regular scale shape and frequency and similar surface features can be observed in recycled cashmere (Figure 4c). Figure 4b displays a pigmented virgin cashmere in which are clearly visible pigment granules unevenly distributed on the surface of the fiber [36]. The same pigment deposition in the fibers can be observed in recycled cashmere (Figure 4d), supporting the considerations already pointed out by the NIR analysis.

The baseline shift makes difficult a visual inspection of the raw NIR spectra and hard to discriminate virgin and recycled cashmere. To eliminate the influences and to enhance the small changes in the spectra, the 2nd derivative was applied to

1 all the spectra collected, but for brevity Figure 5 shows a spectrum for virgin cashmere samples (a) and one for recycled
2 ones (b).
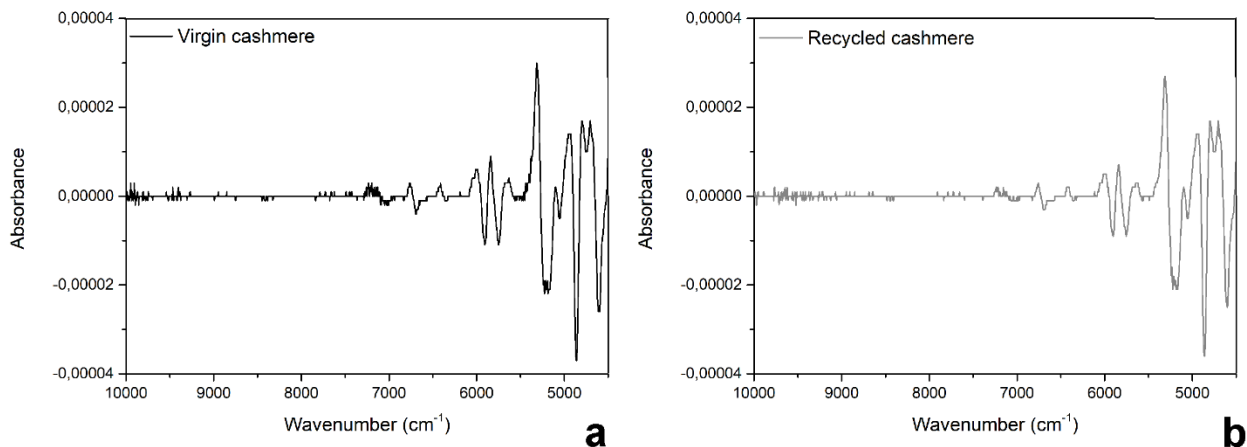
Figure 5: Second derivative spectra of virgin (a) and recycled (b) cashmere

6 After spectral processing, the signal resolution has been significantly improved and the baseline shift has been also
7 reduced. Furthermore, the 2nd derivative spectra of virgin and recycled cashmere are very similar, showing the same
8 characteristic absorption peaks. Actually, no differences can be detected in the spectral range of 5000 and 3700 cm^{-1},
9 region referred to the protein type structure. Indeed, the prevalence of α-helix secondary structure is clearly demonstrated
10 by the presence of the peaks at 4615 cm^{-1} and by the absence of the peak at 4525 cm^{-1} attributed to the β-sheet structure
11 for both the virgin and recycled cashmere [8]. Thus, it can be concluded that the spectral differences are mainly originated
12 from the physical state of the virgin and recycled cashmere.

Classification of virgin and recycled cashmere

14 In order to create a calibration model, 54 samples were randomly selected and the dataset composed of 20 samples (10 of
15 virgin cashmere and 10 of recycled cashmere) were used for external validation. PCR was performed in the range from
16 7500-3700 cm^{-1}, to cover the whole spectral variation. The pretreated data with SNV methods were used to develop
17 regression models with PCR. The PCR shows a R^2 of 0.97, SEE of 0.061 and a SEP of 0.081.

18 All the recorded spectra for the two types of cashmere were analyzed using the principal component analysis, PCA. The
19 PC is a linear combination of spectra and it requires no knowledge of the data set structure and acts to reduce the dimension
20 of the multivariate data. Thus, PC describes the source of variation between the two sets of cashmere. The first principal
21 component explained 91% of variation between the virgin and recycled cashmere whereas the second component is 8.5%.
22 The interpretation of the results of a principal component analysis is usually carried out by visualization of the component
23 scores. Figure 6 shows the score plot of PC1 vs PC2.
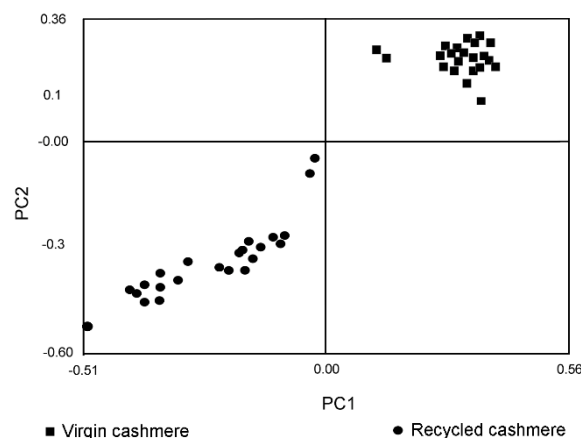
Figure 6: Score plot PC1 vs PC2

7

1 A clustering tendency related with the fiber origin, virgin or recycled, is clearly displayed, with a distribution form the
2 left to the right. Essentially, the recycled cashmere is located in the quadrant where PC1 and PC2 were negative.
3 Contrarily, the virgin sample is situated where the PC1 and PC2 value were positive. In other words, a good discrimination
4 between virgin and recycled cashmere was obtained. Thus, the PC analysis revealed a clustering tendency that can be
5 related with differences in physical and morphology characteristics of the fibers [7]. The differences between the fibers,
6 mainly due to the recycling process, creates changes in the physical structure of the cashmere. These morphological
7 differences between the two cashmeres can be stressed by the chemometric analysis leading to a creation of two different
8 classes and allowing a discrimination of chemically similar samples.

9 *SIMCA modelling and identification*

10 The SIMCA recognition technology was applied for the NIR model of virgin and recycled cashmere. It is essential to
11 perform mathematical pre-treatments to reduce the systematic noise, such as baseline variation, light scattering and path
12 length differences. In this study, a data pre-processing method was applied which was the Standard Normal Variate
13 transformation (SNV) [33]. Generally, the SNV process requires the de-trending to remove the effect of the baseline shift
14 and the curvilinearity, but, in this case, was not used. Thus, the SIMCA technology allows to evaluate the interclass
15 distance from the clustering tendency of the virgin and recycled cashmere when subjected to PC analysis. The value of
16 the interclass distance represents the differences between the recycled and virgin cashmere. Actually, if this value is high,
17 the diversity between the samples is great, whereas a low value indicates high similarity between the samples. Therefore,
18 a high interclass distance leads to an easy classification and identification. On the contrary, a low value indicates that the
19 two samples are difficult to discriminate [20]. The interclass distance evaluated after modelling with SIMCA is 249.77,
20 consequently well above the limit of 3.0 regarded as significant to identify two groups of samples as different classes,
21 hence a correct classification of fibers has been obtained.

22 The prediction capacity of the SIMCA model was tested, adding to the 54 samples previously analyzed, 20 samples (10
23 of recycled and 10 of virgin cashmere fibers) in order to make a validation of the model. The obtained results are listed
24 in Table 2.

25

Sample	Recognition rate (%)	Rejection rate (%)
Virgin cashmere	98% (36/37)	100% (37/37)
Recycled cashmere	100% (37/37)	100% (37/37)

26 **Table 2:** Percentages of recognition and rejection from SIMCA modelling

27 As shown in Table 2, the recycled cashmere has been recognized as belonging to the respective class, giving 100%
28 recognition. Furthermore, the recycled sample has been rejected from virgin cashmere class with a 100% of rejection.
29 Regarding the virgin cashmere, the recognition rate is 98%. This incorrect classification can be related with the very dark
30 pigmentation of the sample. Despite of this result, an accurate classification can be obtained. Furthermore, all samples
31 were rejected from other class, giving 100% of rejection. In the achieved validation, all the samples were correctly
32 identified as belonging to the proper class and no false positive results were found out. This result clearly highlights the
33 powerful of the evaluated method. The technique can be successfully applied for a correct discrimination between virgin
34 and recycled cashmere resulting in a fast and non-destructive method. Therefore, NIR spectroscopy can be easily applied
35 in industrial field for fiber discrimination as a fast screening method to avoid frauds.

36 *Quantitative analysis of virgin and recycled cashmere*

37 In this perspective, it is necessary to recognize the quality of cashmere fibers also when they are in blend. Recycled
38 cashmere fibers are often mixed with different amounts of virgin fibers to obtain yarns with suitable mechanical properties
39 for fabrics re-manufacturing.

40 Therefore, the identification of recycled cashmere in blends with virgin one it has been studied. With a view to prevent
41 possible counterfeiting of samples, the evaluation of the amount of recycled fibers has been carried out using a calibration
42 curve. The calibration was performed using 18 samples produced by carefully mixing known amounts of virgin and
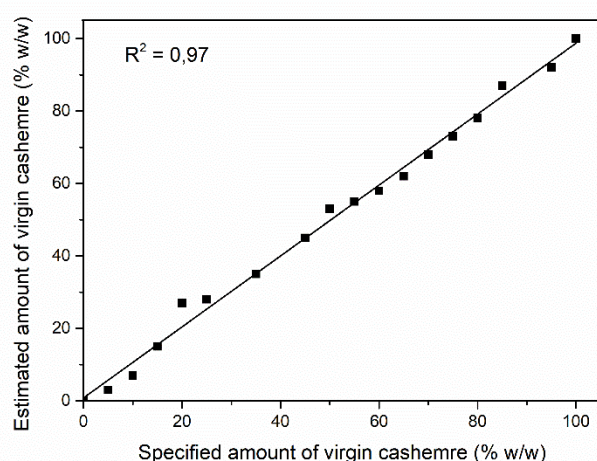43 recycled cashmere. The obtained result is depicted in figure 7:

Figure 7: Specified values (virgin cashmere % w/w) vs. estimated values

Figure 7 compares the % w/w of virgin cashmere amount with the amount predicted by NIR spectral evaluation. The Standard Error of the Estimate (SEE) which is the square root of the residual variance divided by the degrees of freedom, was found out to be 5.2. The magnitude of the expected when independent sample were predicted using the model were calculated as the Standard Error of Prediction (SEP) and it was about 5.8 for a mean value of 50. Also, the R^2 was evaluated and a value of 0.97 was obtained from the calibration. From the calibration curve, it is possible to deduce that up to 5% of recycled cashmere can be detected within a virgin cashmere blend [8]. Thus, this method can be successfully applied to identify even small quantity of recycled cashmere, preventing possible adulteration.

Conclusion

In this work, NIR spectroscopy coupled with chemometric method has been successfully used for the identification of virgin and recycled cashmere and for the quantitative analysis of cashmere blends. The differences between fibers were evaluated throughout the elaboration of the NIR spectra and correlated with physical and morphological characteristics rather than chemical features of the cashmere fibers. The SIMCA method was used for the classification of samples and the interclass distance found is large enough to allow a sure identification of the samples. The prediction test carried out gave no false positive results allowing a correct identification of unknown samples. Furthermore, the results of the quantitative calibration of cashmere blends show an SEP value of 5.8 w/w indicates that it is possible to correctly identify the amount of recycled cashmere in blend with virgin fibers, even if the amount of recycled fibers is only 5% (w/w). Thus, the NIR spectroscopy coupled with chemometric analysis is proved to be a suitable tool for a fast and sure identification of recycled and virgin cashmere fibers and to be successfully applied in industrial fields for preventing possible adulteration of textile luxury product.

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