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Technical study on the early twentieth century's embroidered women waistcoat in Gyalrong Tibetan area in Sichuan, China

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Abstract

In the early twentieth century, traditional handicraft was challenged by the latest technology in China. It is reflected by ethnic costumes combining new and old, as in the waistcoat of this study. This waistcoat made at Gyalrong Tibetan area in Sichuan, China, displays unique local features in terms of its brilliant colors and comprehensive craftsmanship. This study employs techniques such as optical microscopy, infrared spectroscopy, scanning electron microscope and high performance liquid chromatography-mass spectrometry to investigate various aspects of this waistcoat, including its fabrics and dyes. The results showed that the waistcoat was primarily made of cotton and silk, with a bamboo paper layer, and that silk as well as twisted gold and silver threads were employed for the embroidery. Various embroidery techniques were applied, with patterns, color combinations, and characteristics being consistent with those of Tibetan and Shu (蜀) embroidery. In terms of dyeing technology, a wide range of colors were achieved through multi-step dyeing processes using natural dye stuffs like pagoda bud, and synthetic dyes like magenta. These findings indicates that modern technologies were well integrated into traditional garment manufacture in the early twentieth century in China.

Keywords Textile fabrics, Dyes, Gyalrong Tibetan population, The early twentieth century

Introduction

Textile manufacturing is a chief component of the handicraft industry and also a notable symbol of national culture. China has a long history of textile manufacturing, resulting in diversiform traditional crafts of dyeing, weaving, and embroidery. Dozens of dyes extracted from natural plants have been discovered and utilized, e.g., munjeet, bluegrass, safflower and so on [1, 2]. As for textile raw materials, natural fibers including silk, cotton, wool and bast were commonly used [3]. Embroidery were invented and developed upon the slippy and glossy properties of silk. There are four kinds of embroidery which have been well-known since the Ming Dynasty (1368-1644AD), i.e., Su (苏) embroidery, Shu (蜀) embroidery, Xiang (湘) embroidery and Guangdong (粤) embroidery [4].

In addition to these distinguished embroideries, there are also many ethnic costumes with unique characteristics, such as Gyalrong embroidery. Gyalrong Tibetan population, a special local branch of the Zang (Tibetan) people, is a social group formed after the long-run integration of Zang immigrants and garrisons in the Tang Dynasty (618-907AD). Gyalrong Tibetan people primarily reside in Sichuan province, China, shown in Fig. 1.

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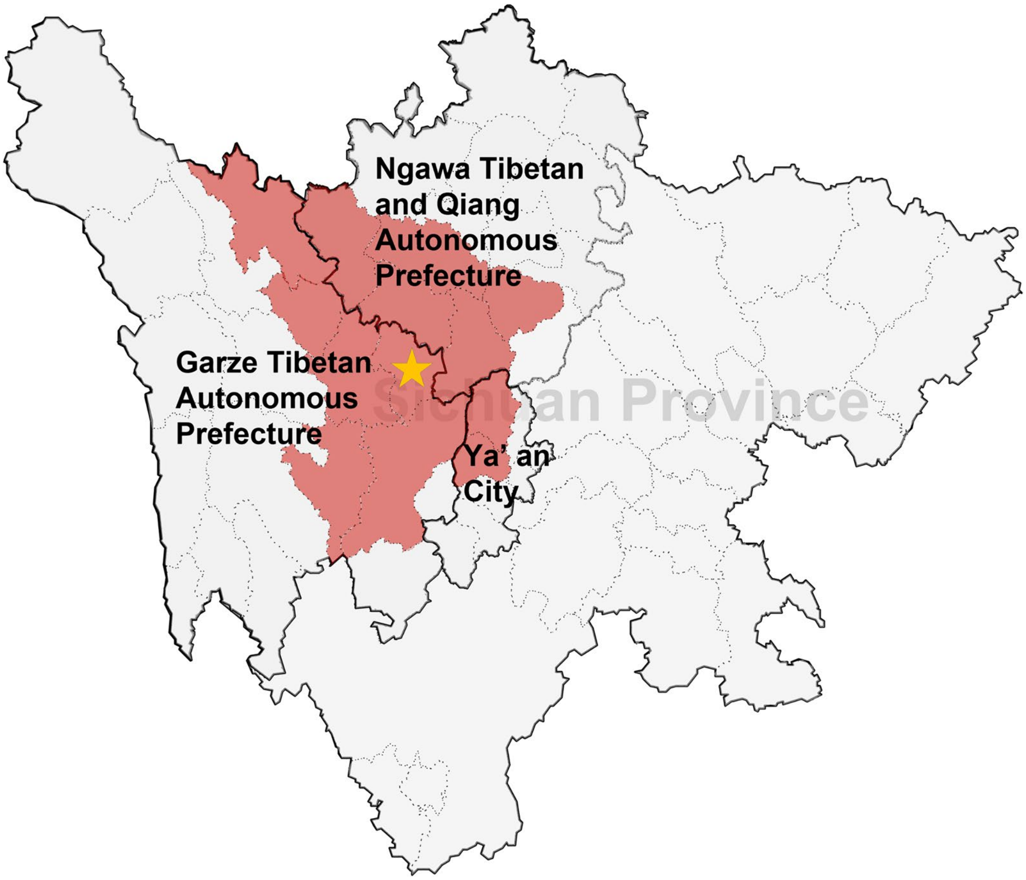

Fig. 1 main distribution area of the Gyalrong Tibetan people (drawn according to [5, 6], the yellow star marks the location of Danba County where the waistcoat was collected)

Located in the north of the Tibetan-Yi Corridor, this area is important for population migration, commercial trade and cultural exchange of the Han, Tibetan, Qiang and Yi populations [5]. Due to its unique geographical position and ethnic background, Gyalrong Tibetan people has developed a distinctive cultural tradition throughout its long history [6]. Under the influence of Qiang (羌) embroidery and Shu embroidery, Gyalrong embroidery was formed in the Ming Dynasty and matured in the Qing Dynasty (1616-1912AD). In the Ming Dynasty, the development of cross-stitch (挑花) and drawnwork (抽纱) techniques in Shu embroidery greatly promoted the development of Gyalrong embroidery [7]. During the late Qing Dynasty (1840-1912AD), a traditional Tibetan embroidery applique embroidery (贴绣) significantly evolved. Simultaneously, there was a notable increase in cultural exchanges between the Han population and Gyalrong Tibetan population. This interaction had a profound impact on the design and craftsmanship of Gyalrong clothing, especially the incorporation of Panjin embroidery (盘金绣) from Shu embroidery. The formation of female inheritance custom promoted the maturity and stability of Gyalrong embroidery techniques [8]. Quite a number of magnificent costumes with Qing Dynasty characteristics were retained and worn by Gyalrong women during major festival celebrations [5].

In recent years, the field researches on Gyalrong Tibetan costumes have gradually increased. The basic stitching, pattern, color, material and craftsmanship of Gyalrong Tibetan costumes have been investigated in order to inherit the traditional costumes and innovative new costume designs [9, 10]. However, there is few scientific research on Gyalrong Tibetan historical costumes. By studying the Gyalrong clothing during the early twentieth century, we can broaden our insights into cultural exchanges between the Han and Gyalrong Tibetan populations at that time, providing valuable evidence for the integration of novel industrial technology into traditional Han and Gyalrong Tibetan cultures.

Since the second half of the nineteenth century, the invention and production of synthetic dyes [11] and artificial fibers [12] have gradually affected traditional processes. Synthetic dyes were introduced to China in the late nineteenth century and soon occupied a major market share, because they were less expensive, more readily available than natural dyes and not affected by seasons [13]. By the end of the nineteenth century, methods had been developed to modify and dissolve cellulose from cotton and wood pulp, and to extrude the solution to produce "artificial silk". The most successful ones were viscose and acetate rayon [14]. In the 1930s and 1940s, the polymer hypothesis (long linear organic molecules) has been accepted, enabling the production of Nylon and Terylene [15]. The imported synthetic fibers like Nylon was used on women's cheongsam and stockings. But due to the scarcity of these materials, their impact on domestic textile materials was limited [16, 17].

The analysis of textiles in the early twentieth century can reveal the utilization of diverse products in textile manufacturing, and provide insights into acceptance of novel things by the traditional handicraft during that period. The examination of textile technology aids in the exploration of the social production level and cultural characteristics of that period. However, synthetic dyes and artificial fibers complicate the analysis of modern artifacts. In this study, microscopic observation and infrared spectroscopy were chosen to identify the textile fibers, and high performance liquid chromatography-mass spectrometry (HPLC–MS) was chosen to analyze the dyes. Microscopic observation and infrared spectroscopy can effectively identify the raw materials due to the different morphologies and chemical compositions of various fibers [18, 19]. For example, Jemo D and Parac-Osterman D used optical and scanning electron microscopy to investigate the raw material of a chasuble in the nineteenth century and confirmed the fibers were silk and cotton by infrared spectroscopy [20]. HPLC–MS provides details of dye compositions in a high accuracy with only a tiny amount of samples [21–23], which is suitable for identifying a variety of natural and synthetic dyes. Tamburini D et al. analyzed several synthetic dyes such as malachite green and fuchsine by using high performance liquid chromatography diode array detector coupled to mass spectrometry [24], showing that this method is appropriate for complex dye analysis.

Materials and methods

Materials

The research object of this study is a collection of Museum of Tibetan Culture, which was collected from Danba County, Sichuan Province, China. It is a women's waistcoat in the early twentieth century, as shown in Fig. 2.

Typical details of the waistcoat are shown in Fig. 3. The white interior of the fabric is made by plain weaving. Both the front and back of the waistcoat are flower purple twill adorned with braid decoration made of silver thread and brilliant embroidery. Interlayer is made of yellow lining paper, serving as the central support. The edges are crafted with black satin piping. The central design on both sides of the fabric is featured with patterns of a traditional Chinese Ruyi (如意) made by applique embroidery. The embroidery uses beige white satin as the ground for depicting abundant patterns such as birds, flowers, pines, and so on. Different needling methods were adopted, including plain stitching(平针), winding(缠绕针), knitting(编针) techniques and panjin embroidery. Among them, the use of panjin embroidery (Fig. 3d) and the large gaps of the winding technique (Fig. 3i) were influenced by Shu embroidery. According to the above information of the pattern, material, and embroidery techniques of the waistcoat, it can be inferred that the owner is likely a wealthy middle-aged woman. Identified by the experts in ethnology and Tibetology, the waistcoat belongs to a characteristic regional style of Gyalrong in the early twentieth century [6]. The color combination and stitching of this costume also exhibit the characteristics of Shu embroidery characteristics.

The waistcoat is in good condition with only minor color fading and fiber wear-out, and has been passed down through generations. Without undergoing burial and excavation processes, the waistcoat in current condition closely resembles its original appearance. Therefore, it is believed that this waistcoat can serve as a good representation of the production process during that period.

Typical samples were collected to gain a comprehensive understanding of the primary raw materials, production process, and dyeing techniques used in this waistcoat, as well as its historical and cultural significance. Specific sample information is shown in Table 1.

Analytical methods

Optical microscopy

The details of the waistcoat were observed with a stereomicroscope (HiROX DIGITAL MICROSCOPE kh-8700, T0215). For each sample, a small amount of sample fiber was contained in Canadian resin on a slide covered with coverslip. The longitudinal morphology of fabric fibers was observed and photographed by optical microscope (LEICA DM 4000 M).

Fourier transform infrared spectroscopy (FTIR)

The samples were directly tested by attenuated totally reflection (ATR) Fourier transform infrared spectroscope (Thermo scientific Nicolet Is5) to determine the type of raw material based on its chemical features. The testing

Fig. 2 purple satin embroidered women's waistcoat in Gyalrong Tibetan area of Sichuan Province, China (**a**. outer front, **b**. outer back, **c**. inner)

range was 4000–400 cm^{-1} with a resolution of 4 cm^{-1} and 16 accumulation times.

Scanning electron microscopy (SEM) with energy dispersive spectroscopy (EDS)

The gold and silver threads were observed by scanning electron microscope (Hitachi TM3030) under low vacuum mode to determine the material and workmanship. A small portion of sample No.4 and No.5 was excised and subsequently encapsulated in epoxy resin. Then the cross-section was ground, polished and gilded. The minimum test time for EDS was 90 s. The working distance ranged between 6.5 mm and 9.5 mm, with a high voltage of 15 kV. The detection limit of the instrument is 0.1%.

To ensure the accuracy of EDS, the instrument has been calibrated by standard samples $CuZn_{39}Pb_3$. The accuracy of the detection of Au content was verified by testing a gold bar with known Au content that meet standards (GB/T 26021 and Q/CHNAU 0004–2019).

High performance liquid chromatography-mass spectrometry (HPLC–MS)

The dyes were extracted and analyzed by high performance liquid chromatography-mass spectrometry according to [25]. Approximately 0.4 mg yarns of each sample (the flat gold thread of No. 4 was wiped off in advance) was extracted with a solution of pyridine/water/0.1 M oxalic acid in water (95/95/10) and heating at 85 ℃ for 30 min. After drying in nitrogen, the extract was dissolved in MeOH/H_2O (1/1). Then the solution was centrifuged. 20 μL supernatant was injected into the HPLC column by an autoinjector.

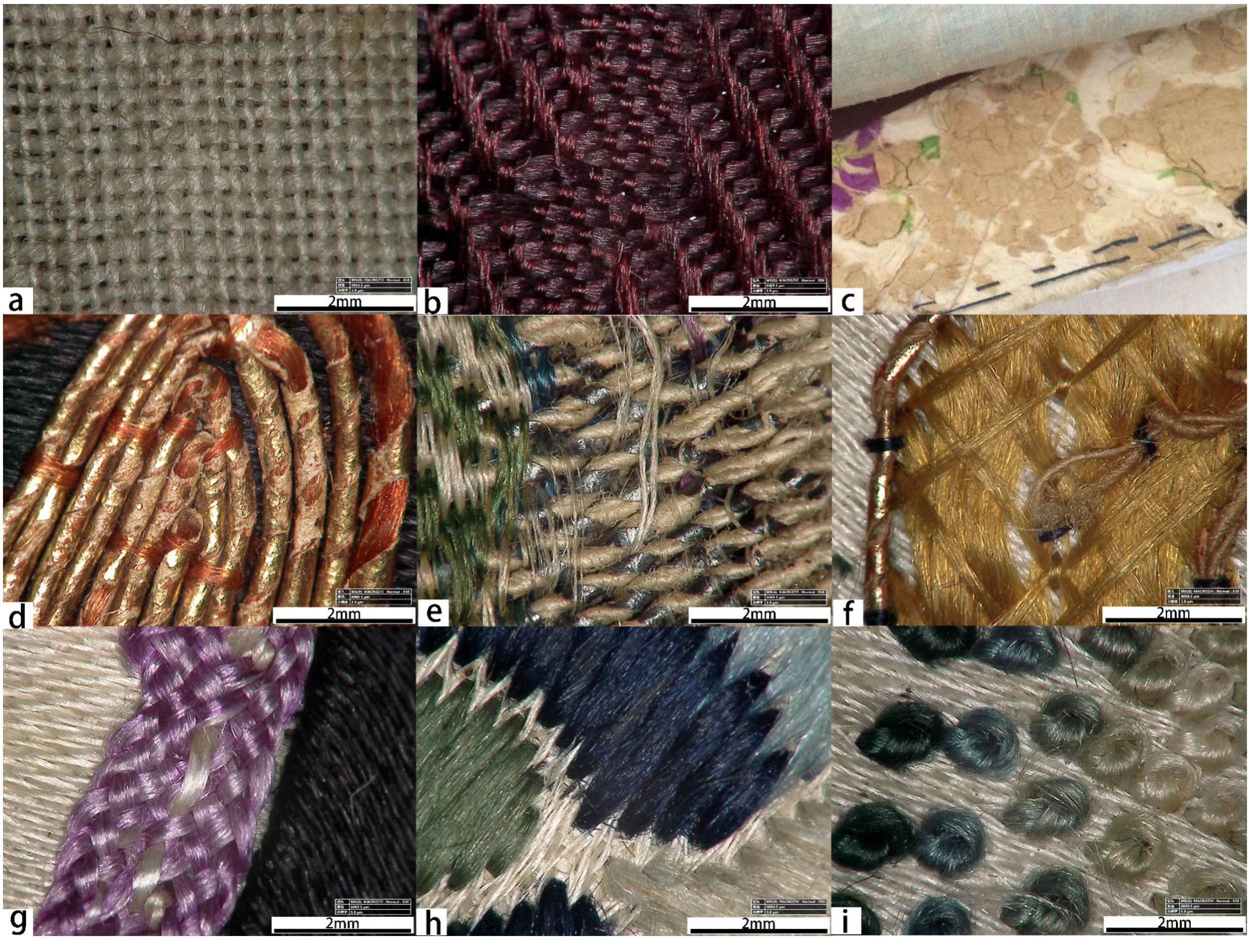

Fig. 3 typical details of the purple satin embroidered women's waistcoat (**a**. plain weaving, **b**. flower purple twill, **c**. yellow lining paper, **d**. panjin embroidery, **e**. braid decoration made of silver thread, **f**. knitting technique, **g**. applique embroidery and black satin piping, **h**. plain stitching, **i**. winding technique. **g** and **i** are cited from [6])

Table 1 Sample information of the waistcoat

No	Sampling point	Sample content
1	The interior layer	White fabrics
2	Flower purple twill	Purple fabrics
3	Interlayer lining paper	Paper
4	Gold threads of the embroideries	Gold threads
5	Braid decoration between the flower purple twill and the beige white satin	Silver threads
6	Yellow fabrics of the embroideries	Yellow fabrics
7	Pink fabrics of the embroideries	Pink fabrics
8	Black satin piping	Black fabrics

The liquid chromatography system consists of a binary high-pressure gradient pump, a diode array detector and an automatic sampler (LC-20AD, Shimadzu). The separation was performed on C18 reverse phase chromatography columns (Shimpack XR-ODS, Shimadzu for positive mode; Luna, Phenomenex for negative mode). The column was eluted with water–acetonitrile gradients containing 0.1% formic acid at a flow rate of 0.25 mL/min. The mass spectrometer was a linear ion trap mass spectrometer (LTQ XL, Thermo Scientific). Mass spectra were acquired and processed by XCALIBUR 2.1 Software in the mass range m/z 100–1000. The parameters for the mass spectrometer were set as follows: ion spray voltage 3 kV (positive mode) and 2.5 kV (negative mode); capillary temperature 350 ℃; nitrogen gas as sheath gas and auxiliary gas pressurized with 35 and 15 psi respectively; capillary voltage 35 V (positive mode) and 40 V (negative mode) for the positive and negative modes respectively. MS/MS spectra were obtained by data-dependent acquisition (DDA) using collision-induced dissociation (CID). CID parameters were set according to [25]. Specifically, the isolation width was 2 m/z; normalized collision

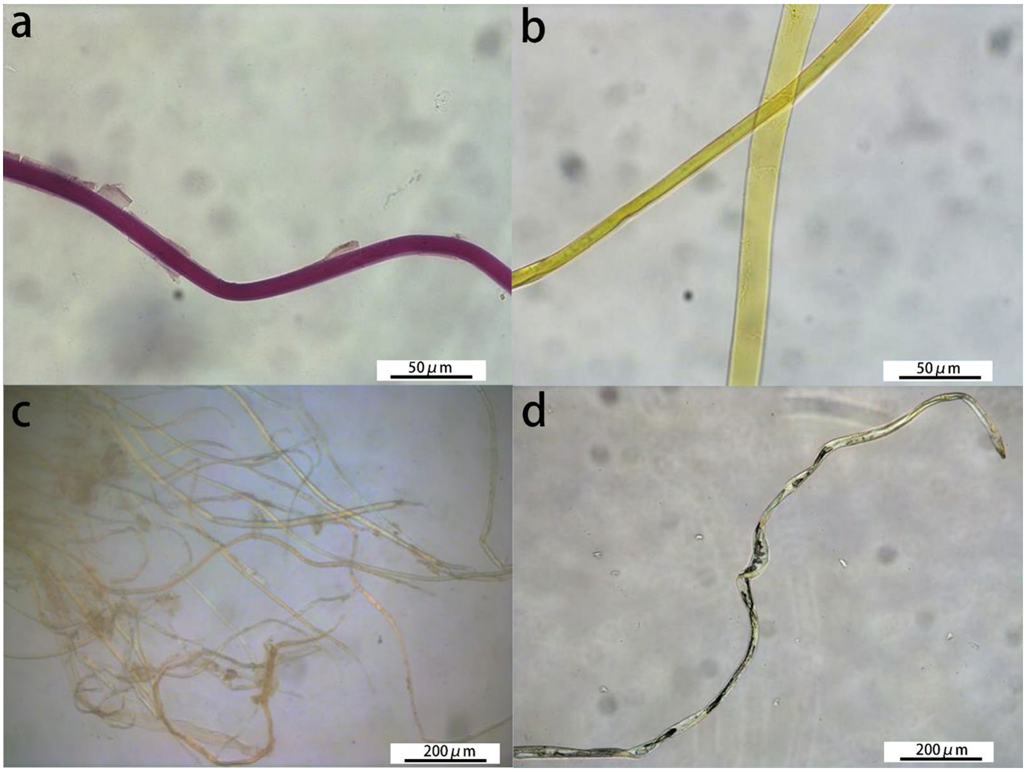

Fig. 4 Typical longitudinal morphologies of **a**: sample No.2; **b**: sample No.6; **c**: sample No.3; **d**: sample No.1 The surface of sample No. 2 and No.6–8 is smooth, without scales, joints, and vertical lines, indicating they are probably silk. Sample No. 2 exhibits a transparent thin layer on some fibers, which is suspected to be residual sericin [26]

energy was 35%; activation Q was 0.25; activation time was 50 ms. The minimum signal required to trigger data-dependent acquisition was set to 1000 counts.

Results and discussion

Fabric materials

The sample taken from the waistcoat was first observed by the optical microscope, and a total of 3 kinds of animal and plant fibers were found. The typical morphologies are shown in Fig. 4.

The majority of fiber cells in sample No. 3 are straight and long, with tapering and pointed ends. They have narrow fiber lumens, thick cell walls, and few pits, which match the features of bamboo fiber [27]. Few catheter cells are short and thick, with open ends and evenly distributed reticulated pores on the wall. A small number of cells exhibit irregular shapes.

The core fibers of samples No. 1 and No. 5 exhibit an apparent twisting phenomenon, large cell lumens, smooth fiber walls, absence of nodularity and pit structures, which suggests they are both cotton fibers. When compared to mercerized cotton, the microscopic characteristics of these two samples differ [28].

Since the longitudinal morphologies of silk and artificial fiber are similar, infrared spectrum analysis was used to further determine the fiber type sample No.2 and No.6–8. The infrared spectrum is shown in Fig. 5.

It can be seen from Fig. 5 that the infrared spectra of the 4 samples are basically the same. Compared with modern silk spectra [29, 30], it can be confirmed that these 4 samples are all silk. The O–H and N–H groups were observed as a broad band at 3279 cm^{-1}, while the N–H stretching band of Nylon is observed as a sharp band at 3320 cm^{-1} [31]. The C = O stretching vibration peak (amide I band) is typically observed at 1699 cm^{-1} and 1625 cm^{-1} [32–35]. The N–H and C-N bending vibrations (amide II band) are mainly observed near 1508 cm^{-1} [32, 35–37]. As for Nylon, the amide I band and amide II band were observed around 1634 cm^{-1} and 1538 cm^{-1} [38]. Amid III band was observed around 1229 cm^{-1}, indicating a random coil conformation [32, 36, 39]. The CH_2 and CH_3 bending vibrations and the C-N stretching vibration in alanine were detected around 1445 cm^{-1} [40, 41] and 1083 cm^{-1}[37, 41]. CH_2 bending vibration in asparagine was detected

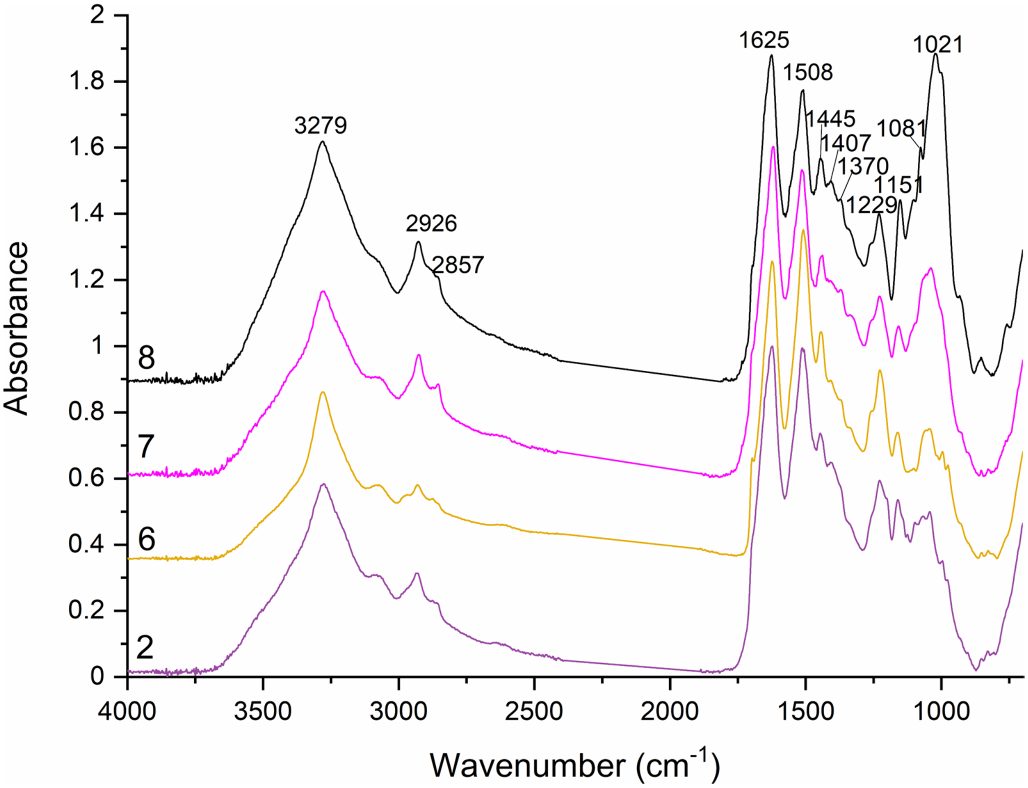

Fig. 5 Fourier transform infrared spectrum of silk sample (curve color corresponds to fiber color)

around 1407 cm^{-1} while C-H bending vibrations were observed near 1367 cm^{-1} [42].

The production process of the gold and silver thread

In order to study the production process of the gold and silver threads, scanning electron microscope was used to observe the gold and silver threads of samples No. 4 and No. 5. The typical structures are shown in Fig. 6.

Shown in Fig. 6a, the diameter of the gold thread is approximately 280 μm. The inner core fibers are untwisted, and the outer layer is made of flat gold thread approximately 570 μm wide without any gaps. As shown in Fig. 6b, the transverse plane of the inner core fibers exhibit an irregularly round and triangular shape, which is the characteristic of silk [43, 44]. This observation is consistent with the results of longitudinal morphological observations under the optical microscope. There are two layers between the inner core fibers and the outermost gold foil. The inner layer has a width of approximately 20 μm, while the outer layer has a width of approximately 16 μm. Based on Fig. 6a, the exposed lining layer of the gold foil has fibers oriented in various directions. It is suspected that these two layers are made of paper, which means that the flat gold thread wrapped around the inner core fibers is gold foil attached to a backing paper with double layers.

There are two traditional Chinese processes for making gold thread, i.e., flat gold thread and twisted gold thread. The flat gold thread is made with paper or animal leather as its backing material. Gold foil is then attached to it and subsequently cut to a specific width [45]. For twisted gold thread, silk or cotton is used as inner core fibers, coated with adhesive material, and the flat gold thread is wrapped in a spiral shape outside the inner core fibers. If bamboo paper is used as the backing material, it must first be wetted. Then, it is brushed with fish glue and framed into a double layer before being pasted with gold foil [46, 47]. According to the structural characteristics of sample No. 4, the embroidered gold thread of this waistcoat is twisted gold thread. The production process involves selecting red, untwisted silk as the inner core fibers, then wrapping and sticking the flat gold thread, which attached to the 2-layer paper base, around the inner core fibers in Z direction (anticlockwise twist from lower right corner to upper left corner) without spacing.

For the silver thread shown in Fig. 6c, d, the diameter is approximately 350 μm. The inner core thread is made up of two-strand yarns wrapping in Z direction. Flat silver thread about 450 μm wide is wrapping around the

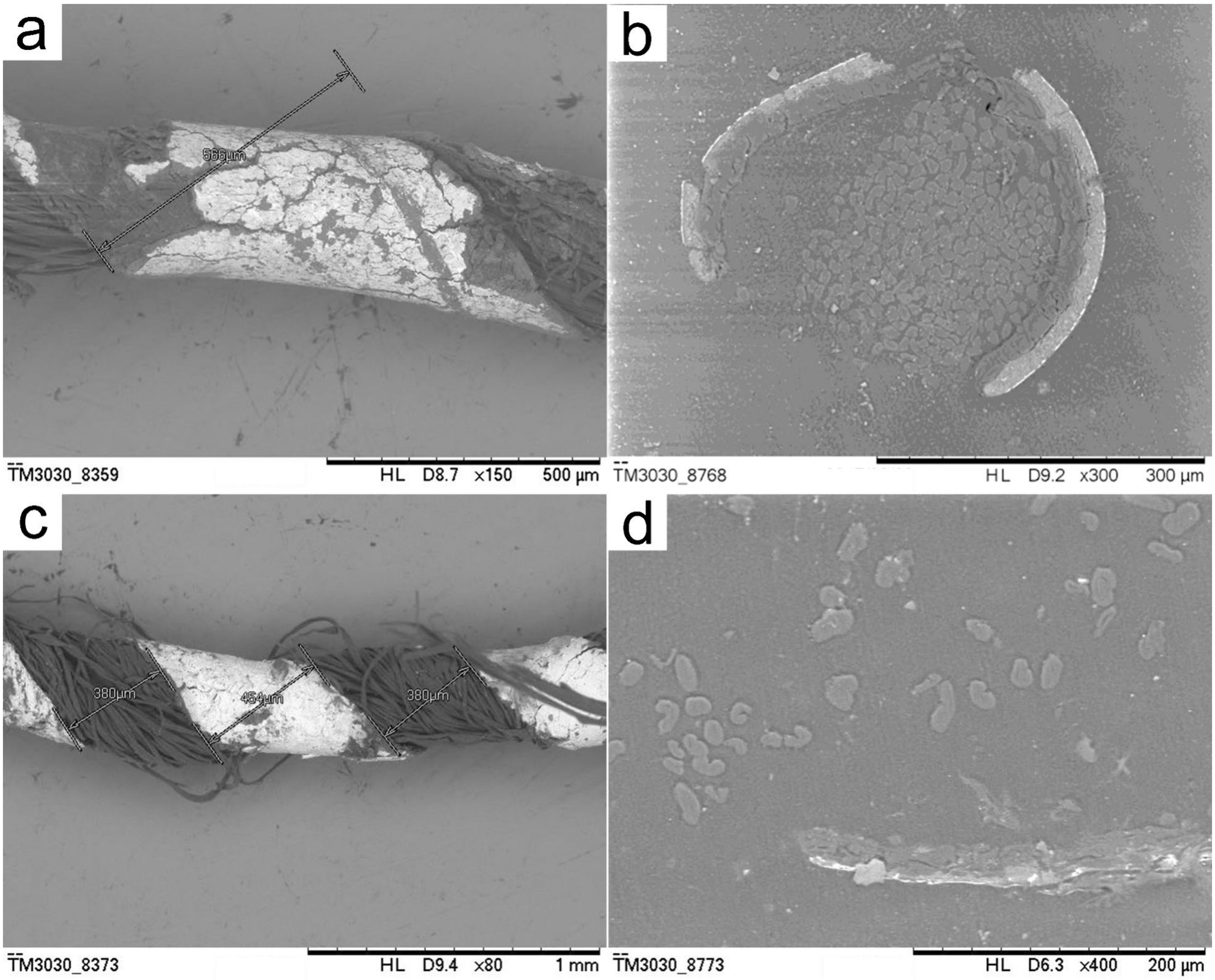

Fig. 6 Backscattered electron micrographs of typical structures (**a**. the gold thread; **b**. the cross-section of the gold thread; **c**. the silver thread and **d**. the cross-section of the silver thread)

inner core thread in Z direction with a gap of 380 μm. The transverse section of the inner core fibers are irregular with a lumen in the center, which can be identified as cotton fiber based on its longitudinal section shape [44]. Since most of the fiber cross sections are in waist shape, which differs significantly from the oval section shape of mercerized cotton, they are not mercerized cotton [28]. This conclusion is consistent with the observations under the optical microscope. Unlike the gold thread, only a 30 μm wide layer between the inner core fibers and the outermost silver foil. Obviously, the silver thread used for cording this waistcoat is twisted silver thread. The production process involves selecting plain colored Z-twisted cotton thread as the inner core thread and wrapping flat silver thread with a Z-direction interval of approximately 380 μm on its outer surface.

The composition of the gold and silver threads were analyzed by EDS. The results are shown in Table 2.

The ratio of gold and silver atoms in the gold foil used in the gold thread is approximately 3:2, corresponding

Table 2 The element information of the gold and silver thread (at. %)

Sample No	Samples	O	Mg	Al	Si	S	Cl	Ag	Au
4	gold thread	35.39		26.71	8.31			12.11	17.48
5	silver thread	40.91	1.53	20.07	3.70	10.93	0.28	22.58	

to a mass ratio of approximately 74% gold and 26% silver. This composition is referred to as "small red gold", or 18 K gold foil. This type of gold foil exhibits high brightness, a moderate price, resistance to oxidation or discoloration, and can remain unchanged for approximately 6–7 years at room temperature. It is commonly utilized in various gold decoration scenarios [48]. A similar metal content of twisted gold thread has also been found on another Qing Dynasty drama costume [49], suggesting that twisted gold thread with low gold content was popular in folk clothing.

The ratio of silver to sulfur atoms in the silver foil of the silver wire is approximately 2:1, which suggests that the silver has partially oxidized to silver sulfide during the preservation process. This observation is consistent with the gray color of silver.

Dyes

The dye analysis of the colorful samples was carried out by liquid chromatography-mass spectrometry. The results are shown in Table 3. Chromatograms and mass spectra are shown in supplementary information 1.

A mixture of pararosaniline, rosaniline, magenta II and new fuchsine indicated the presence of magenta [25] in sample No. 2. Magenta, known as fuchsine, was first synthesized by Verguin in 1859 [50]. It is capable of dyeing silk to produce a bright magenta color or multiple color combinations. A mixture of bis-desmethyl malachite green, desmethyl malachite green and malachite green was also detected in the sample No.2, which indicated the presence of malachite green [25]. Malachite green is an alkaline dye invented by Dobner and Fisher in 1878 [11]. The waistcoat pink embroidery thread was dyed solely with magenta, while the purple fabric was dyed with a combination of magenta and malachite green. There are two traditional ways to dye purple in China. One is to use a single plant. The root of gromwell was used for dyeing purple since the Warring States period (476-221BC) [51, 52]. Sappanwood with ferrous sulphate can also dye purple [52]. Another common way to dye purple was to combine the blue dyes and red dyes [52, 53]. The purple cloth used for the waistcoat was mixed with synthetic dyes of pink and green color, suggesting that the makers had found an alternative to replace natural plant purple. Although the leveling ability of these two silk dyes is satisfactory, the wet treatment's firmness is poor, resulting in color fading after washing. This is the primary reason for the extensive red fading of the waistcoat.

Table 3 The main dye chemical composition of different color sample fibers

Sample No	Color	Possible compound	Retention time (min)	λmax (nm)	$[M—H]^-$ (m/z)	$[M+H]^+$/ $[M]^{a+}$ (m/z)	MS/MS fragments (m/z)
2	Purple	Pararosaniline	7.96	285, 541		288	168, 195, 273, 288
		Rosaniline	8.48	286, 546		302	195, 209, 287, 302
		Magenta II	8.95	289, 547		316	209, 223, 301, 316
		New fuchsine	9.40	286, 551		330	223, 330
		Bis-desmethyl malachite green	9.97	411, 591		301	194, 223, 286, 301
		Desmethyl malachite green	10.36	315, 419, 608		315	194, 208, 237, 300, 315
		Malachite green	10.73	319, 426, 622		329	208, 251, 313, 329
4	Red	Pararosaniline	7.94	280, 541		288	168, 195, 273, 288
		Rosaniline	8.44	284, 546		302	195, 209, 287, 302
		Magenta II	8.92	282, 546		316	209, 223, 301, 316
		New fuchsine	9.36	287, 546		330	223, 330
		Bisdemethoxycurcumin	13.69	416		309	147, 189, 225, 239
		Demethoxycurcumin	13.94	420		339	151, 175, 177, 229, 245, 269, 321
		Curcumin	14.22	426		369	175, 245, 285, 299
6	Yellow	Rutin	7.86	255, 354	609		301
		Sulfuretin	10.07	270, 394	269		135, 201, 225, 269
7	Pink	Pararosaniline	7.94	285, 542		288	168, 195, 273, 288
		Rosaniline	8.46	288, 546		302	195, 209, 287, 302
		Magenta II	8.94	289, 547		316	209, 223, 301, 316
		New fuchsine	9.38	290, 551		330	223, 330
8	Black	Ellagic acid	8.04	255, 354	301		185, 229, 257, 301
		Indirubin	14.59	289, 355, 544		263	219, 235, 245, 263

In addition to magenta, bisdemethoxycurcumin, demethoxycurcumin and curcumin were detected in the sample No.4, which indicated the presence of curcumin [54, 55]. Curcumin is primarily present in the rhizomes of plants belonging to the families of Zingiberaceae and Araceae. In China, turmeric (*Curcuma longa* L. or other plants in genus *Curcuma*), called Jiang Huang (姜黄) or Yu Jin (郁金) during different times, is commonly used as dyes [56]. Research shows that the rhizome of *C. longa* contains a significant amount of colorants (1.8–5.4%), making it suitable for dyeing [57]. Turmeric can directly dye cotton, wool, silk and other fibers, and can get different colors with different metal salts. The combination of a red natural dyestuff and a yellow natural dyestuff for a red shade was common in ancient China, such as sappanwood and turmeric, safflower and amur cork tree and so on [53]. In this case, the combination of turmeric and magenta to get red is an innovation.

The deprotonated molecule at m/z 609 matched rutin according to the retention time and the secondary mass spectrometry [58], while the deprotonated molecule at m/z 269 matched sulphuretin [54]. Rutin is the main dyeing component of pagoda (*Sophora japonica*) bud [56], also known as Huai Mi (槐米). It is documented that Huai Mi was collected from *Sophora japonica* over 10 years old, boiled in the water, dried and kneaded into a cake. It can be used directly or with metal mordant for home use [59]. Sulfuretin exists in many plants, such as smoketree (黄栌, *Cotinus coggygria* variants), *Coreopsis* spp. and so on. In ancient China, Huai Mi and smoketree were commonly used for dyeing different shades of yellow [53]. The yellow silk threads of this waistcoat was probably dyed with the flower bud of *Sophora japonica* and the branch of *Cotinus coggygria* variants by traditional means.

Ellagic acid and indirubin were detected in the sample No.8. Ellagic acid is a naturally polyphenolic compound found in various plant tissues, including soft fruits and nuts, such as acorn cup and Chinese gallnut. The traditional black dyeing methods commonly used in Sichuan, China, include the “acorn cup green(椀子青)” silk dyeing method and the “gallnut green(倍子青)” silk dyeing method. The former is dyed with acorn cup, Chinese gallnut and melanterite, while the latter is dyed with indigo and repeatedly soaked with Chinese gallnut and melanterite. Indigo is used as the base color to ensure that the presented color are not reddish [60]. The characteristic markers of indigo are indigotin and indirubin, which are isomers and share almost the same mass spectrum. According to the UV–vis absorption peaks, the protonated molecule at m/z 263 is indirubin [54, 55]. Indirubin detected in the sample No.8 indicated the presence of indigo. Indigo can be extracted from bluegrass and has been used for thousands of years in China [61]. Indigo blue was successfully synthesized in 1880 and was imported into China at the beginning of the twentieth century [13]. Because indirubin was a by-product in early synthetic indigo [62, 63], both plant-based and synthetic indigo could be used in this waistcoat. Since the main components of the dye are ellagic acid and indigo, which aligns with the characteristics of the traditional “gallnut green” silk dyeing method, the black satin piping of the waistcoat may be dyed with Chinese gallnut and bluegrass.

Discussion

The above results indicate that the fabrics of this waistcoat is made of natural fibers, and the twisted gold and silver threads are produced using traditional techniques. The inner fabric is composed of cotton fibers, which exhibit good air permeability and provide enhanced wearing comfort. The primary fabric and embroidery on the outer surface are crafted from silk, enhancing the clothing’s luster and overall aesthetic. The middle interlayer is constructed from bamboo paper, providing support for the numerous embroidery patterns on the outer surface, preventing possible deformation due to excessive embroidery. It should be noted that cotton fibers have not undergone mercerization. Although mercerized cotton and synthetic fibers have been invented and introduced in China in the early twentieth century, this Gyalrong clothing may not have employed these novel materials due to a lack of widespread introduction of raw materials in inland regions such as Sichuan, coupled with traditional manufacturing customs.

Panjin embroidery, a traditional Chinese embroidery technique, uses gold and silver thread to assemble figures and fixes them with silk thread stitching. During the Qing Dynasty, Panjin embroidery was introduced to Gyalrong Tibetan area along with embroidery products and women skilled in embroidery. This technique was well-received by Gyalrong Tibetan people. Nowadays, some embroiderers in Gyalrong Tibetan area still master the art of Panjin embroidery [7]. This waistcoat features a significant amount of Panjin embroidery, showcasing the integration of this technique into traditional Gyalrong clothing. The production of gold and silver thread is closely linked to the development of the gold and silver foil manufacturing industry. Gold foil manufacturing originated during the Six Dynasties period (222-589AD) and flourished during the Qing Dynasty, with the main production centers located in the southern regions of the Yangtze River. However, in the early twentieth century, various factors such as war and foreign competition caused a decline in gold foil production, resulting in a slump in sales and ultimately leading to a cessation of production in 1937 [48]. Despite the depression period for gold and silver foil production during that time, this Gyalrong waistcoat features an abundance of twisted gold and silver threads. This is likely due to the relative isolation of the Gyalrong Tibetan area from external influences compared to coastal areas, which help preserve the traditional manufacturing practices.

The use of dyes in the waistcoat indicates the innovative utilization of novel items by Gyalrong Tibetan people. Not only are there natural plant-dyed colors, such as yellow and black, by using traditional dyeing techniques, but also colors like magenta and purple obtained through synthetic dyes, like magenta and malachite green. Additionally, the red color was obtained using a combination of synthetic dye magenta and plant dye turmeric. Since no evidence of synthetic dyes production in the Gyalrong Tibetan area in the early twentieth century was found, it is likely that synthetic dyes entered the Gyalrong Tibetan area through commerce. The cultural exchanges between Gyalrong Tibetan population and Han population have been taking place for centuries. Synthetic dyes were likely introduced to Gyalrong Tibetan area through contacts with Han population. The utilization of synthetic dyes indicates that Gyalrong Tibetan people have well integrated synthetic dyes into traditional handicraft and applied appropriately in their costumes.

Conclusion

By means of optical microscopy, infrared spectroscopy, scanning electron microscope and high performance liquid chromatography-mass spectrometry, it is found that the materials used in this waistcoat are traditional natural fibers such as silk, cotton, and bamboo, combined with gold and silver threads, instead of synthetic fibers or mercerized cotton which entered the Chinese market in the early twentieth century. There are both traditional plant dyeing methods such as turmeric, pagoda bud, smoketree, Chinese gallnut, and synthetic dyes such as magenta and malachite green. Additionally, red silk is made through a combination of synthetic dyes magenta and plant turmeric. This indicates that the Gyalrong Tibetans maintained communication with the external world during the early twentieth century. Although they might not have been fully abreast of the latest trends, they were nonetheless influenced by modern industrial products. The Gyalrong Tibetan people have selectively adopted new technologies and combined them with traditional craftsmanship to create exquisite clothing.

Supplementary Information

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Supplementary material 1.

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Author contributions

The researches were designed and organized by Wu Xiaohong. Fundings were provided by Wu Xiaohong and Wang Yue. The research object and its background information were provided by Zhan Lidan. The sample was collected by Zhan Lidan and Wang yue. OM, FTIR, SEM analysis were performed by Wang Yue and Zhou Yihang. HPLC-MS analysis was performed by Liu Jian. The manuscript was written by Wang Yue and revised by Zhou Yihang and Wu Xiaohong. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analysis results obtained in the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests

The authors declare that they have no competing interests.

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