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Research Article

Structural and Thermal Properties of Ethiopian Eri and Mulberry Silk Fibres

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Silk fibre has received attention in the biomedical sector rather than textile production because of its excellent biocompatibility properties in the past century. Although silk fibre properties are different from area to area, it has created an opportunity in the biomedical sector to develop new silk-based medical textile products. This research work aimed to study the structural, physical, mechanical, and thermal properties of Ethiopian silkworm cocoon's filament. Eri and mulberry silk fibre properties such as morphological structure, chemical properties, linear density, filament length, tensile strength, elongation, thermal property, and luster were measured using ES ISO and ASTM standard methods. Statistical analysis result showed that eri silk fibre from Arba Minch had water removal temperature between 100°C and 125°C with a degradation temperature of around 400°C and eri silk fibre from both Addis Ababa and Awassa had an almost similar water removal temperature around 100°C and degradation temperature around 420°C. Tensile strength and elongation of both eri and mulberry silk fibres had significant differences among each region. The highest tensile strength of 4.47 cN was observed from Addis Ababa, and the highest elongation of 20.01% was found from the Arba Minch eri silk fibre. The coarser linear density of 2.496 dtex from Arba Minch and finer count of 2.392 dtex were exhibited from Awassa. Arba Minch eri silk fibre had the highest filament length of 403.04 m and the least fibre length of 399.2 m recorded at Addis Ababa, and a better whiteness (Rd) value of 58.21 was observed at Arba Minch eri silk fibre. Bivoltine and multivoltine mulberry silk fibres had an average tensile strength of 8.01 and 11.83 cN, elongation of 10.3 and 12.1%, fineness of 3.2 and 3.16 dtex, and filament length of 1208.6 and 1028.26 m, respectively, in the same place of Arba Minch. The morphological structure of eri silk fibre from each region had an almost smooth and clean surface, but bivoltine and multivoltine mulberry silk fibres were somehow rough and had spots. According to the comparison results, Ethiopian silk fibres can be utilised more in the biomedical application and competitive in the global market.

1. Introduction

In the last decades, silk fibre has been broadly used for the biomedical application rather than textile apparel usage due to its biocompatibility, slow degradability, and other physical properties. In Ethiopia, silk has a strong attraction to the people starting from the early period of the Axum Kingdom. In the global textile parlance, the term "silk" refers to the mulberry silk because the bulk of world silk production, about 95%, is of mulberry origin [1]. However, silk has two main types, namely, mulberry and nonmulberry silks. This classification is based on the kind of plants that silkworms are fed. Except for mulberry, other varieties of silks are generally termed as nonmulberry silks [2]. Despite the arrival of less costly synthetic fabric such as rayon and nylon, the properties and characteristics of silk account for its continued significant demand [3]. Many investigations were done on the characterisation of different types of silk fibres and their potential of application [4–11]. The silk fibre is used for making parachute, tyre manufacture, soft sky jackets, comforters and sleeping bags, scarves, and ties [12–14]. Ayano Koyrita has researched on Ethiopian eri and mulberry silk fibres, particularly on Bahir Dar, Awassa, and Awash Melkasa silk production areas. However, Addis

Ababa and Arba Minch silk fibres were not included in the study, and silk fibre properties such as length, tensile strength, elongation, and chemical and thermal properties have not been thoroughly addressed [10]. Rajkhowa et al. investigated the tensile stress-strain and recovery behaviour of all the four commercial varieties of Indian silk fibres, namely, mulberry, tasar, eri, and muga, researched along with their structures. They found that mulberry silk fibre is much finer and has crystallites of smaller size, higher molecular orientation, and a more compact overall packing of molecules than nonmulberry silk fibres [14].

Researchers reported that silk fibre has been used most extensively as sutures for centuries and recognized increasingly as a prospective material for biomedical textiles, because of the availability of large quantities of material from the textile industry, the ease of processing, controllable degradability, remarkable mechanical properties, and biocompatibility. Silk-based biomaterials have been explored and engineered for the fabrication of various biomedical textiles and fibre-based implants such as sutures, arterial grafts, heart valves, hernia and prolapsed repair meshes, heart implants supports, and prosthetic ligaments and tendons, among other devices [15, 16].

In another research work, the semi-alkali-treated silk fibres were incorporated as a reinforcing agent, while a mixture of 20% maleic anhydride-grafted polypropylene (MAPP) and time commercial grade polypropylene (PP) was used as a matrix element [17]. Andiyappan et al. found that eri silk is suitable for wound-dressing applications due to its biochemical composition and lower sericin content, which enhances cell attachment behaviour [18]. Similarly, Chiriac et al. stated that silk fibre characteristics are interesting for medical applications such as the induction of no or only a weak immune response, low bacterial adherence, and inherent biodegradability, among other desirable attributes. These findings have encouraged the research community to study their potential for applications as implantable materials and tissue scaffolds [19]. More recent studies with well-defined silkworm silk fibres and films suggest that the core silk fibroin fibres exhibit comparable biocompatibility in vitro and in vivo with other commonly used biomaterials such as polylactic acid and collagen [20].

Silk fibres are traditionally produced by sericulture specifically ericulture and moriculture are agro-based production systems for eri and mulberry fibres, respectively. Sericulture means the technique involves the planting of plants on which the silkworm grows, the production of cocoons, reeling, and spinning of cocoons for production of yarn [21]. Environmental conditions such as biotic factors are of particular importance for the success of sericulture. Among the abiotic factors, temperature plays a major role in the growth and productivity of silkworms [22]. Other researchers reported that the good quality cocoons are produced within a temperature range of 22–27°C and that cocoon quality is poorer above these levels [23]. The environmental factors, in particular temperature and humidity at the time of rearing and moisture content of mulberry leaf, affect the growth of the silkworm [24]. Silk is more sensitive to light than any other natural fibre [25]. As cited by [26], according to Market Research analysis in 2017, the global silk market is being projected to rise to USD 16.94 billion by 2021, and it is important that developing countries must increase and improve the quality of their silk to compete in the global market.

Silk products produced in Ethiopia are organic by nature as the plantation for rearing uses natural fertilisers. There is a high potential of production of eri and mulberry silkworms in different Ethiopian areas such as Bahir Dar, Awassa, Adama, Addis Ababa, Shebedino (SNNP), Arba Minch (Ent Chano Chalba), Gomugofa (Miirab Abay), Wolaita (Sodo), Ambo Town, and Awash Melkasa sites. To use this natural resource properly, the silk fibre properties need to be characterised. In this investigation, the structural and thermal properties of eri and mulberry silk fibres, including bivoltine and multivoltine mulberry silk fibres, are characterised, and their potential application is indicated.

2. Materials and Methods

2.1. Materials. The eri silk fibre was collected from three main rearing regions of Ethiopia, such as Addis Ababa, Awassa, and Arba Minch. These three sites were selected for sample collection by their organised and well-managed silk production in the country. Mulberry silks (bivoltine and multivoltine) were collected from the Arba Minch area. All types of silk fibres were collected in the same season (18–29°C and 40–70% relative humidity) from September to November, 2019. However, Arba Minch is also conditioning (23–28°C temperature and 70–75% relative humidity) the rearing atmosphere and prevents diseases from silkworms.

2.2. Methods. Eri silkworms feed on castor plant, and mulberry silks feed mulberry leave in all sites. The degumming process was carried out at 1 : 40 mass liquor ratio using 2 g/L soda ash, 2 g/L wetting agent, and 10 g/L Marseilles soap treat for 2 hrs at 90°C at pH 9.5–10 in the bath. From each silk fibre, 0.5 kg samples were collected randomly, and their properties such as chemical properties, fibre length, tensile strength, elongation, luster, and thermal property were measured according to ES ISO and ASTM standards.

2.2.1. Morphological Structure. Leica biological microscope Model 2086C was used to determine the structure of eri and mulberry silk fibres. The testing procedures were done according to the ASTM D276 standard.

2.2.2. FTIR Analysis. A PerkinElmer FTIR instrument was used for the analysis of components of the eri and mulberry silk fibres. The spectrum version of the instrument was 10.03.06. To fix the test specimen on the instrument, a 11 N pressure force was applied. Measurement was done within the spectral range 400–4000 cm^{-1} with a resolution of 4 cm^{-1}.

2.2.3. Thermal Properties. The PerkinElmer Differential Scanning Calorimeter (DSC4000 model) was used to determine the thermal properties of the eri and mulberry silk fibres. The tests were conducted in accordance with the machine manual using 2 g of silk fibres. During the measurement, the range of temperature was 50–450°C at a scanning rate of 10°C/min and 50 ml/min nitrogen gas flow was applied.

2.2.4. Fibre Length. The length of the cocoon filament corresponds to the varieties of silkworms. The range of total length of mulberry silk filament is from 600 to 1500 m, of which 80 percent is reliable while the remainder is removed as waste [27]. In Ethiopia, the total waste will reach 20–23 percent due to degumming process [10, 13]. To determine the fibre length, 100 samples of the fibres were taken from eri and mulberry silk fibres for each location. The single fibre length was measured, and the average was used for comparison between the same and different areas.

2.2.5. Fibre Fineness. Fibre fineness, fibre count, linear density, and fibre number are all expressions of the finesse of a fibre. Linear density can be expressed either by measuring the mass of a known length of the direct fibre system (mass/length) or by measuring the length of a known mass of the indirect system (length/mass) fibre. To determine the linear density of both eri and mulberry silk fibres, it was done by measuring the length of the silk fibres, weighed on an electronic balance, and calculated by dividing the mass of fibres (g) by length of fibre (m). The linear density of the tested fibres was reported in the form of dtex ($10 \times$ tex).

2.2.6. Fibre Luster. Luster is one of the most important parameters of silk fibre that makes it as superior from other natural fibres apart from length and strength. A spectrophotometer was used to analyze the color and luster of all samples of eri silk fibre from each site (Addis Ababa, Arba Minch, and Awassa) and mulberry from Arba Minch. This instrument was used to quantify the maximum Rd (whiteness) and +b (yellowness) property of each sample using a bundle of fibres.

2.2.7. Tensile Strength and Elongation. Favimate® instrument was used to measure single fibre tensile strength and elongation at the same time. Twenty tests were measured for each sample to study tensile strength and elongation at a speed of 20 mm/min for 25 mm gauge length as per the ES ISO 5079 standard.

2.2.8. Statistical Analysis. Statistical analysis of the data was conducted using SPSS version 21 for Windows statistical software. Differences between the groups with $p \leq 0.05$ were considered to be statistically significant. A p value greater than 0.05 means that no effect was observed or indicates a 5% risk of concluding that a difference exists when there is no actual difference.

3. Results and Discussion

3.1. Morphological Structure. As shown in Figures 1(a)–1(c), the morphological structure of eri silk fibre from every region had a spotless and smooth surface, but as it is seen from Figures 1(d) and 1(e), bivoltine and multivoltine mulberry silk fibres had rough and spot surface due to higher amount of impurity of sericin that remains during degumming process.

3.2. FTIR Analysis. Figure 2 shows FTIR spectrum peaks of bivoltine (BV) and multivoltine (MV) mulberry silk fibres from Arba Minch. It is remarkable that the peaks of entire bivoltine appear in 2037 and 442 cm^{-1} while the peak of the multivoltine anticipated at 2034 cm^{-1} corresponding to a medium CN stretch (nitrile functional group stretching). In bivoltine and multivoltine, the CN stretching peak was seen at 2037 cm^{-1} and 2034 cm^{-1} and had a similar appearance with slight difference contributing for strength, i.e., bivoltine had stronger intensity than multivoltine for that a peak that appeared in this peak was due to CN stretching of alkynes groups. The 2840 cm^{-1} bivoltine and 2880 cm^{-1} multivoltine peaks indicate the C-H (alkene) group stretching in the silk fibre. Stretch free strong and sharp O-H for alcohol and water OH stretch functional groups in silk are represented by the peaks at 3695 cm^{-1} to 3490 cm^{-1} [28, 29].

Figure 2 shows the functional group of the amide I absorption band at 1615 and 1615 cm^{-1} (C=O stretch), amide II absorption band at 1512 and 1510 cm^{-1} (N-H Bending), and amide III band absorption at 1216 and 1216 cm^{-1} (C–N stretching), respectively, for Awasssa (Hawassa), Arba Minch, and Addis Ababa eri silk filament. Previous investigators reported that the above absorption bands are attributed to the ů-sheet structure of the silk fibroin [30].

3.3. Thermal Properties. As demonstrated in Figure 3, DSC results showed that eri silk fibre from both Addis Ababa and Awassa had almost similar water removal temperatures around 100°C. However, eri silk fibre from Arba Minch had 125°C water removal temperature. This is most probably Arba Minch eri silk fibre contains less moisture or has higher amount of sericin as compared to others. Previous researchers reported that silk fibres with highest sericin need high temperature to loss their moisture [29]. Yazawa et al. also reported that similar concepts of water content did not affect the thermal degradation temperature but did influence the water removal behaviour. By increasing the water content of silk, the water molecules were removed at lower temperatures, indicating that the amount of free water in silk materials increased [31].

The fibre maintained stable heat flow without any significant change up to the glass transition region. After the glass transition (Tg) regions, the samples thermally degraded at Tg without showing a melting peak. It is clearly shown that the degradation peak temperature was at 420°C for Awassa and Addis Ababa eri silk fibres and Arba Minch eri silk fibre degraded at 400°C. The same findings 334–450°C of

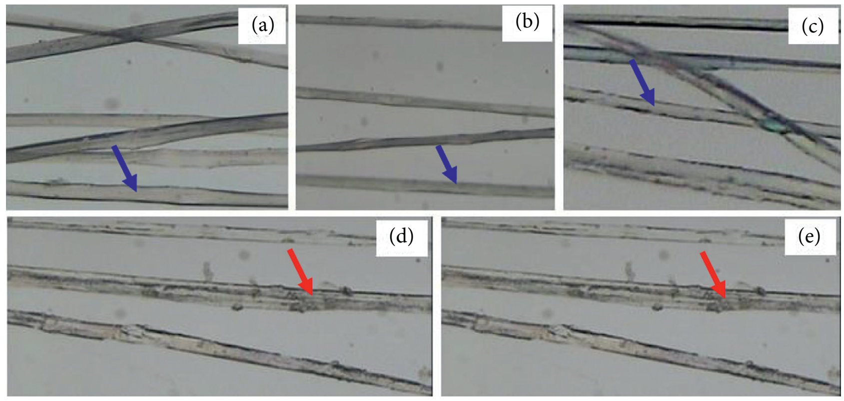

FIGURE 1: Microscopic structure of eri and mulberry silk fibres: (a) Awassa, (b) Addis Ababa, (c) Arba Minch, (d) bivoltine, and (e) multivoltine.

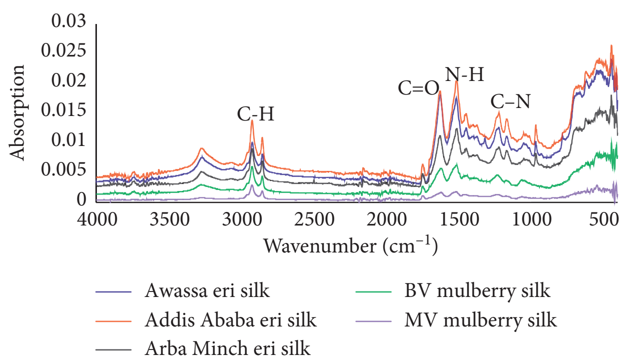

FIGURE 2: FTIR spectrum of bivoltine and multivoltine mulberry silks.

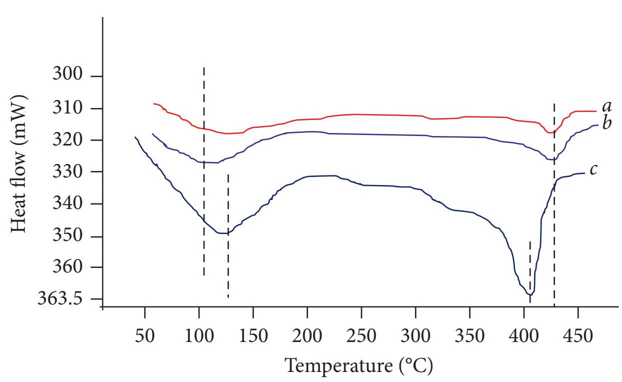

FIGURE 3: DSC thermograms of eri silk fibres: (a) Awassa, (b) Addis Ababa, and (c) Arba Minch.

degradation points were obtained by earlier researchers for mulberry and eri silk fibres [29, 31].

3.4. Length of Silk Fibres. As the evidence in Figure 4, the length of eri silk fibres was 403.21, 400.1, and 399 m for Arba Minch, Awassa, and Addis Ababa, respectively. From mulberry silk fibre, bivoltine had the highest length of 1208.61 m next to multivoltine silk fibre 1028.26 m.

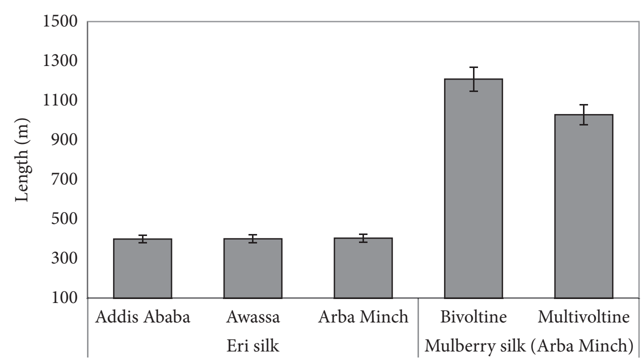

FIGURE 4: Length of eri and mulberry silk fibres.

However, the results in Table 1 demonstrated that the statistical analysis proved that there was no significant change within each group and between eri and mulberry silk fibres at a p value of 0.742. As reported in previous research work [32], Indian eri and mulberry silk fibre total filament length of eri is 400–500 m whereas it is 1200–1600 m in case of bivoltine and 900–1200 m in case of multivoltine mulberry silk, and Ethiopian silk fibre length falls in this range.

As shown from Table 1, fibre length and fineness of eri silk fibres were an insignificant change at a p value of 0.549 and 0.742, respectively. On the contrary, tensile strength and elongation of a different region of eri silk fibres had a significant change at a p value of 0.005 and p value of 0.000, respectively. When a p value (significant value or sig.) is greater than 0.05, it indicates that the mean value of fibre properties is almost the same and reverse to p value is less than 0.05. Therefore, the statistical result proves that filament length and fibre fineness of eri silk fibres from each site had the same results.

3.5. Fibre Fineness. Bivoltine and multivoltine mulberry silk fibres demonstrated the highest value of linear density with a slight difference between them, i.e., multivoltine mulberry silk fibre had higher value of linear density as shown in Figure 5. Eri silk fibres from Arba Minch had the highest value of linear density (2.496 dtex), but eri silk fibre from Addis Ababa showed the lowest value (2.392 dtex) of linear

Table 1: Analysis of variance of eri silk fibres.

		Sum of squares	df	Mean square	F	p value
Length (m)	Between groups	496.488	2	248.244	0.606	0.549
	Within groups	23345.340	57	409.567		
Fineness (dtex)	Between groups	0.112	2	0.056	0.300	0.742
	Within groups	10.636	57	0.187		
Tensile strength (cN)	Between groups	1.404	2	0.702	5.431	0.005
	Within groups	7.368	57	0.129		
Elongation (%)	Between groups	58.121	2	29.061	36.26	0.000
	Within groups	45.673	57	0.801		

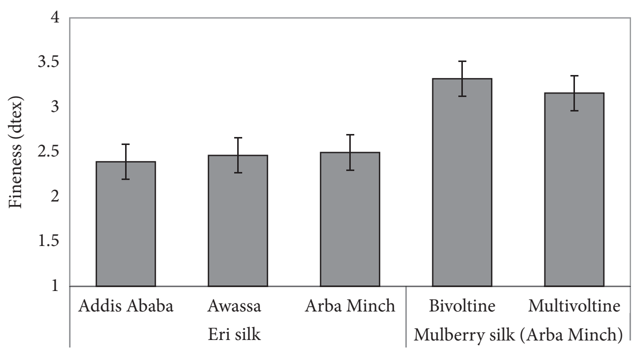

Figure 5: Fineness of silk fibres.

density next to eri silk fibre from Awassa (2.463 dtex). The same finding was observed by [10]. This is because silk worm varieties are many, and the filaments they produce are also diverse in characteristics. Even in the same species, the filaments they produce vary because the environmental conditions and the host plant they could use are different. Fineness of silk fibre varies from 1 dtex to 5 dtex depending on type and place of fibres, while eri and mulberry silk takes fineness ranges of 1 dtex to 3 dtex [33, 34]. Therefore, the finer eri silk fibre had found from Addis Ababa, Awassa, and Arba Minch, respectively. This is because, by the direct count system, the courser increased as linear density increased. Generally, the test result demonstrated that bivoltine and multivoltine mulberry silk fibres are courser than eri silk fibres.

Tables 1 and 2 demonstrated that linear density (fineness) and filament length were not significant changed within eri silk fibres and between bivoltine and multivoltine mulberry silk fibres since the p value is greater than 0.005. This is because silk fibre fineness and length are mostly dependent on silkworm species and degumming process. Mulberry silk fibres are longer than eri silk filaments. The same findings are reported in previous investigation [32].

3.6. Tensile Strength. The tensile strength of the bivoltine mulberry silk fibre exhibited the lower coefficient of variation than multivoltine, and eri silk fibre from Awassa showed the highest coefficient of variation as seen from Table 3. However, the tensile strength of eri fibres from Addis Ababa, and eri and multivoltine from Arba Minch had a medium coefficient of variation. This result revealed that bivoltine mulberry silk fibre had better uniformity in tensile strength, and eri silk fibre from Awassa had the lowest uniformity of tensile strength based on their standard deviation and coefficient of variation. On the other hand, the tensile strength of eri silk fibre from Addis Ababa had the lowest range, and multivoltine had a higher range between individual tests. As evident from Table 3, eri silk fibre from Awassa exhibited the highest tensile strength (4.47 cN) and the lowest tenacity recorded at Arba Minch (4.11 cN). Multivoltine silk fibre had the highest tenacity (11.83 cN) followed by bivoltine (8.01 cN) mulberry silk fibre. As the test result presented, multivoltine mulberry silk fibre had the uppermost tenacity value compared with other regional eri silk fibres and bivoltine. However, all sites of eri silk fibre were significantly different at a p value of 0.00. As seen in Table 2, bivoltine and multivoltine silk fibres had a significant change at an F value of 444.420 and p value of 0.000.

In general, mulberry silk fibre had high strength and low elongation at break in comparison to nonmulberry silk fibres. These findings confirm with the earlier research reports [14, 35, 36]. This is because mulberry silk fibres have more compact structure relatively than nonmulberry silk fibres [33]. The internal compact arrangement contributes to resist to the load and cannot easily break during stretching.

3.7. Elongation. As evident from Table 3, elongation of eri silk fibre from Arba Minch exhibited the highest coefficient of variation, and eri silk fibre from Awassa showed the lowest coefficient of variation. The result showed that eri silk fibre from Arba Minch had the lowest uniformity in elongation, and eri silk fibre from Awassa had the best uniformity. This result demonstrated that eri silk fibre from Addis Ababa had a higher difference of elongation between the maximum and minimum value. Table 3 demonstrates that eri silk fibre from Arba Minch had lowest (high fluctuation) uniformity in elongation while Awassa's eri silk fibres showed good uniformity. This result demonstrates that eri silk fibre from Addis Ababa has a significant difference of elongation between the maximum and minimum value. Tables 1 and 2 show the analysis of variance of eri and mulberry silk fibres, and the elongation was a significant change for both type of fibres at a p value of 0.000. The test results also revealed that the elongation of eri silk fibre from Awassa and Addis Ababa had the lowest and the highest

Table 2: Analysis of variance of mulberry silk fibres.

		Sum of squares	*df*	Mean square	*F*	*p* value
Length (m)	Between groups	123662.184	1	123662.184	6.789	0.13
	Within groups	692201.349	38	18215.825		
Fineness (dtex)	Between groups	0.008	1	0.008	0.064	0.802
	Within groups	5.029	38	0.132		
Tensile strength (cN)	Between groups	145.924	1	145.924	444.4	0.000
	Within groups	12.477	38	0.328		
Elongation (%)	Between groups	32.400	1	32.400	118.9	0.000
	Within groups	10.351	38	0.272		

Table 3: Statistical descriptions of tensile strength and elongation of eri and mulberry silk.

Properties	Eri silk fibres						Mulberry silk fibres			
	T(cN)	E (%)	T(cN)	E (%)	T(cN)	E (%)	T(cN)	E (%)	T(cN)	E (%)
Location	Addis Ababa		Arba Minch		Awassa		Arba Minch (BV)		Arba Minch (MV)	
Mean	4.3800	17.60	4.1100	20.010	4.4700	18.86	8.0100	10.30	11.830	12.100
SD	0.3130	0.515	0.3788	1.419	0.3826	0.355	0.4338	0.448	0.684	0.586
CV	7.15	2.93	9.22	7.09	8.56	1.88	5.42	4.35	5.79	4.85
Minimum	3.8700	16.88	3.2700	17.140	3.7800	18.13	7.1700	9.340	10.450	11.350
Maximum	4.9600	18.69	4.9600	22.600	5.1600	19.47	8.6200	10.92	12.850	12.990
Range	1.0900	1.810	1.6900	5.460	1.3800	1.340	1.4500	1.580	2.400	1.640

T = tensile strength; E = elongation; BV = bivoltine; MV = multivoltine.

range value between individuals, respectively. Generally, eri silk fibres have greater elongation than mulberry silk fibres. This corroborates with the previous report by [36]. If the amorphous regions have randomly arranged chains, as is the case for nonmulberry silk fibres, they can continue to extend at almost a constant load or with slight increase in load [14].

3.8. Silk Fibre Luster. Arba Minch eri silk fibre had the highest whiteness (Rd) value (58.21) followed by Awassa (51) then Addis Ababa (47.1). According to spectrometer result, from mulberry silk fibres, bivoltine had the highest whiteness value (41.7), and multivoltine had the least whiteness value (37.6). Statistically, luster property of both bivoltine and multivoltine mulberry silk fibres had no significant difference at a p value of 0.05. Similarly, eri silk fibres from different areas had insignificant changes with a p value of 0.170 whiteness and a p value of 0.296 for yellowness. Therefore, the test results determined the yellowness and whiteness of eri silk fibre from each site showing almost similar results. Silk filament darkness is the presence of pigments in the sericin layers, which cause the silk fibre color. This color is not permanent and washes away with the sericin during the degumming process. Therefore, the right type of degumming process should be performed for each type of silk filaments. There are diverse hues of color including but limited to white, yellow, yellowish green, and golden yellow [27]. If the sericin content is increased, fibre luster decreased. Mulberry silk contains about 20–30% sericin, whereas non-mulberry silk has about 8–15% only [37].

3.9. Comparison of Ethiopian Silk Fibres with Others. India is one of the most known countries by silk fibre production like that of China. Both eri and mulberry silk fibres in India are slightly finer, stronger, and longer than Ethiopian eri and mulberry silk fibres, as shown in Figure 6. Furthermore, the Indian eri and mulberry silk fibres had marginally better elongation. Except for length, other parameters (tensile strength, elongation, and linear density) of Ethiopian eri and mulberry silk fibres had almost similar value with Indian eri and mulberry silk fibres. For this reason, a feeding system of the silkworm, rearing condition for the growth of the silkworm, and methods of the degumming process for the removal of sericin of eri and mulberry silk fibres had a great influence on silk properties difference [10, 13, 38]. In this investigation, it was observed that Ethiopian silk manufacturers lack proper skills in proper feeding, degumming, and handling [10]. A similar concept was reported by [13] and confirmed to this study report. Despite this, statistical analysis proved that Ethiopian eri and mulberry silk fibres had comparable quality with Indian silk fibre. In addition, Indian eri and mulberry silk fibres with mentioned physical and chemical properties are used for biomedical application extensively [38–43]. Therefore, the studied

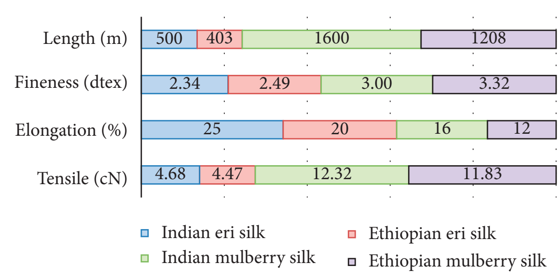

Figure 6: Comparison of Ethiopian and Indian (eri and mulberry) silk fibres.

Ethiopian silk fibres can be used for silk-based biomedical applications.

4. Conclusion

Eri silk fibres were collected from Awassa, Addis Ababa, and Arba Minch areas and mulberry silk fibres with bivoltine and multivoltine stages from the Arba Minch site. Physical, structural, mechanical, and thermal properties of eri and mulberry silk fibres were evaluated. The statistical analysis showed that fibre length, fineness, and luster of the eri silk fibres from different areas were an insignificant change at $p < 0.05$. On the contrary, tensile strength and elongation had the significant difference for each type of silk fibres. Ethiopian eri silk fibre had the range of 3.27–5.16 cN tensile strength, 16.88–22.6% elongation, 1.2–3.84 dtex fineness, and 317.8–452.37 m filament length, and mulberry silk fibre had 7.17–12.85 cN tensile strength, 9.34–12.99% elongation, 2.56–3.94 dtex fineness, and 869.17–1424 m filament length. DSC result proved that eri silk fibre from Arba Minch had 125°C water removal temperature, but other eri and mulberry silk fibres showed that water was removed at 100°C. The degradation points of eri silk fibre from Awassa and Addis Ababa were at 420°C temperature, and Arba Minch silk fibre degraded at 400°C.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

All authors have equal contribution, and they reviewed the file.

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