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An Investigation on Energy Consumption in Yarn Production with Special Reference to Ring Spinning

Abstract
The aim of this study was to evaluate the energy consumption, in general, for ring type yarn manufacturing systems and to examine the energy consumption in a chosen spinning mill by considering the available data including installed power, monthly and yearly energy usage. A simple theoretical approach for predicting the specific energy consumption in a particular yarn type produced in chosen spinning mill was developed. The results obtained by applying this model to a specific yarn was compared with the relevant values available in the literature.

Key words: *energy consumption, yarn manufacturing, ring spinning, textile.*

Introduction

Yarn manufacturing

Yarn can be defined as a thin elongated structure in which fibers hold each other by the effect of friction or twist. If the yarn is produced from staple fibers it is called spun yarn, otherwise it is known as continuous filament yarn. The formation of spun yarn comes true when the basic manufacturing processes such as opening, cleaning, blending, carding, drafting and spinning are performed. In some systems, combing and roving processes are added to these steps. The properties and structure of yarn change not only according to the production steps but also the spinning system used for manufacturing. The system used for yarn formation depends on such factors as fibres to be used, properties of yarn to be produced and economic implications. The spinning systems can be classified as conventional and unconventional . The ring spinning system can be considered as conventional (traditional) system whereas open-end, wrap, air-jet and self-twist spinning systems are unconventional (nontraditional) systems. In all these systems, twisting and winding the yarn on the package is formed by applying different mechanisms. Although studies and developments about new spinning systems go on, the ring and open-end rotor spinning systems are the most widespread system for yarn manufacturing [1 - 6].

The ring spinning system is the oldest spinning system that remains dominant because of the high quality yarns it produces. Ring spinning has various advantages besides disadvantages. This system allows various types and lengths of fibres (natural, man-made) to spin on a wide count range from 6 tex to 118 tex whereas this range is between 17 and 118 tex in rotor spinning. By combing option, the high quality combed yarns which are smoother, brighter and more compact can be produced using the ring system. On the other hand, the ring spinning system has two main problems. The first is low production speed because of frictional contact of ring and traveller, and the yarn tension caused, and the second is high energy consumption that causes high production costs [2 - 6].

Manufacturing cost of yarn

In today's competitive conditions, competing with other manufacturers depends on producing high quality yarns with reasonable costs. Nowadays, the free market determines the price of products irrespective of the administration of spinning mills. For this reason gaining more profit depends on minimising the manufacturing cost of yarns. Especially, cheaper yarns that are produced by Far East countries such as China, Indonesia, draw the attention of consumers. This affects other countries' yarn manufacturers negatively and subjects such as cost calculation and cost minimisation become primarily important [7].

The cost of yarn consists of several factors such as raw material , energy or power, labour, capital etc. The cost of yarn excluding raw material is termed manufacturing cost. The share of the factors in manufacturing cost changes according to the yarn properties, machine operational properties and economical situation of the spinning mill [3, 7].

Table 1 illustrates general shares of cost factors for 20 tex combed cotton yarn the among the chosen countries. Raw material (fibre) forms nearly half of the yarn's total cost and other cost factors such as labor, energy, capital cost of machines, auxiliary material cost and waste make up the remaining part. After raw material, capital and energy costs have the highest proportions in the total . The power or energy cost takes 9% share of the specific yarn total cost in Turkey. This share increases to 17% if the raw material cost is excluded. Since the unit price of energy and labor change independently from spinning mill conditions, reducing these costs depends on minimising energy usage and labor wages.

Since twisting is accomplished by the rotation of the spindle and bobbin, the energy consumption of ring spinning is higher than the other spinning systems. In the ring spinning system, energy is used for feeding the roving to the machine,

Table 1. *Manufacturing cost factors for the chosen countries [8].*

Countries	Manufacturing Cost Factors For Chosen Countries (2003), %						
	Brazil	China	India	Italy	Korea	Turkey	USA
Raw material	50	61	51	40	53	49	44
Waste	7	11	7	6	8	8	6
Labor	2	2	2	24	8	4	19
Energy	4	8	12	10	6	9	6
Auxiliary material	4	4	5	3	4	4	4
Capital	32	14	23	17	21	26	21
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

drafting and rotation of the spindle. At least, 85% of the total power requirement of a ring frame is consumed in driving the spindles, depending on details such as yarn count, package size and spindle speed and the remainder is consumed by drafting and lifter mechanisms [6].

Various studies have been done to determine the energy cost and consumption of the ring spinning system [2, 3]. International Textile Manufacturer Federation [8] has done the comparison of manufacturing costs of textile processes covering spinning, texturing, weaving and knitting in their yearly technical report. This report includes calculated costs for specific ring and open-end rotor spun yarn among the chosen countries.

The cost factors affecting ring and open-end rotor yarn total cost were investigated by Kuşçuoğlu [9]. The labor and energy cost of a chosen spinning mill was examined and costs of different types of yarns with changing machine parameters were evaluated by Koç and Kuşçuoğlu [10, 11]. Örtlek *et al.* [12], compared the calculated cost of 20 tex ring, open-end and Vortex (MVS) yarns were compared with each other. It was found that the energy cost of 1 kg of ring yarn is the highest of the three. Kaplan [7] studied the cost factors which make up the total product cost for the textile industry including spinning, weaving and finishing and the product cost of chosen ring yarn by using empirical formulas, taking into regard specific operating conditions and selected machine parameters .

Energy is necessary for each step of spinning processes to drive machines, air conditioning and lighting, but the highest energy consumption occurs during the spinning process in spinning machines [13]. Another study which handled energy conservation in the textile industry focused on the electricity consumption of each step of ring spinning for the modern and traditional factory [13]. Tarakçıoğlu [14] showed that electrical energy consumption of 1 kg of yarn changes between 2.7 kWh/kg and 4 kWh/kg. Additionally, it was pointed out that thermal energy alternating between 1.1 MJ/kg and 4.7 MJ/kg is necessary for processes such as fixation besides electrical energy needs. General assessment for energy consumption and conservation in fiber-producing and textile industries was done by Kim et al. [15] while determining the power requirement of a specific ring and open-end spinning machine with chosen machine parameters.

Since the highest power is required in spinning machines, many studies have been carried out to determine the power demand of spinning machines. Krause and Soliman [16] attempted to find a general formula for calculating power/energy consumption per 1 kg yarn in ring and open-end rotor machines. It was found that in the coarse yarn range (tex>60) the open-end rotor machine needed less energy per kg of yarn than the ring frame for warp yarns, for finer yarns (tex<30), on the other hand, the oe-rotor machine demanded more energy per kg of yarn than ring frame. It was reported that the factors affecting the power demand of the ring system were ring diameter, balloon height, spindle speed and traveller mass [6].

A specific formula was developed to determine the power consumption of bare spindle (without bobbin) by Ye [17]. It was shown that oil resistance, upper bearing system and friction between footstep bearing and spindle blade tip cause the power consumption of the spindle driving unit in the ring spinning system. A Detailed study was done by Tang et al. [18, 19] in order to determine the distribution of power requirements during yarn winding in ring spinning. A general equation for determining the power requirement of ayarn winding system was established by using parameters such as winding on time, yarn count, mass of the yarn winding package. Tang et al. [20] also established a model based on an analysis of power distribution for predicting the ratio of energy consumption to yarn-production for a full package during yarn winding in ring spinning. Chang et al theoretically and experimentally investigated the effect of yarn hairiness on energy consumption and found that the more hairiness the yarn has the higher the energy consumption during winding in the ring spinning system [21].

In this study, general information about the energy consumption of spinning mills is given and that of the chosen spinning mill was analyzed by using data including installed power, as well as monthly and yearly energy usage. In addition to this, a simple approach for calculating the specific energy consumption of specific yarn was developed. The calculation of specific energy consumption of particular yarn produced in the chosen spinning mill was done using the formulas recommended and the results obtained were compared with the relevant values given in the literature.

Energy consumption in yarn manufacturing

General energy usage in ring spinning

Energy is generally used for operating machines, air conditioning and illuminating the atmosphere where yarns are manufactured in spinning mills. In addition to these, compressors which provide compressed air to the spinning line use energy. Two types of energy can be used in a specific spinning mill; electrical energy and thermal energy. Machines, air conditioning, lamps used for illumination and compressors consume electrical energy while the thermal energy is consumed by air conditioning and processes such as fixation of yarns. Generally thermal energy is obtained from coal, diesel oil, fuel oil, natural gas and steam [7, 22].

Table 2 shows the energy consumption of a specific combed yarn in a modern factory with its production steps. It can be seen from the table that 221.1kWh energy is used for a given spinning line

Table 2. *Energy consumption of specific combed ring yarn [13].*

Production Steps	Electricity consumption of specific combed yarn per 1000 spindles for each process	
	kWh/1000 spindles	Share, %
Blowing Room	16.7	7.5
Carding	17.7	8
Combing	10.9	5
Drawing-Roving	9.1	4
Ring Spinning	66.1	30
Yarn Finishing Treatments	14.7	6.5
SUB TOTAL	135.2	61
Air Conditioning	85.9	39
TOTAL	**221.1**	**100**

of 1000 spindles, 61% of which is consumed by machines and the highest energy consumption with 30% share occurs at the spinning stage.

The energy usage and energy cost of both 20 tex combed ring-spun yarn and 20 tex open-end yarn for the chosen countries are illustrated in Table 3. The amount of energy needed for ring yarn changes between 3.49 - 3.62 kWh/kg while the energy needed for open-end yarn is between 2.44 and 2.58 kWh/kg. Since the electrical energy prices are different in the chosen countries, the energy cost differs from country to country although the consumption is nearly the same.

Energy consumption of chosen spinning mill

In order to obtain the necessary information about energy consumption of a specific spinning mill, one which is able to spin every kind of staple fibre (i.e. cotton, linen, polyester, viscone) in a wide count range using both ring and open-end systems was chosen. This spinning mill included not only machines used for manufacturing (blowing room, carding, combing, drawing, roving, spinning, winding), but also included 5 air conditioning systems, 2 compressors and 2555 lamps for illumination. Besides this, the chosen spinning mill used only electrical energy.

The unit power needed for corresponding machines in production line and power for the air conditioning system, compressors and lamps can be seen in Table 4. Installed power is a power needed for the each equipment if there is no energy loss; the actual power was calculated taking into consideration energy loss or energy efficiency. The total installed and actual power needed for each equipment given in the table was obtained by multiplying the number of machines with unit power required. The subtotal of each equipment group is also shown, i.e. subtotal of actual power necessary for carding machines is 229.5 kW. In addition, the last column of the table shows the share of actual power required for each equipment group in the total actual power consumption, i.e. carding machines form 9.44% of the total actual power consumption. The amount of total actual power in the chosen spinning mill was determined as 2432.8 kW in which machines, air conditioning, compressors and illumination were included and the machines con-

Table 3. *Energy usage for specific ring and open-end yarn [8].*

Countries	Electrical energy prices, $/kWh	Ring yarn (Combed)		Open-End Yarn	
		Energy consumption, kWh/kg	Energy cost, $/kg	Energy consumption, kWh/kg	Energy cost, $/kg
China	0.066	3.49	0.23	2.58	0.17
India	0.084	3.57	0.30	2.50	0.21
Turkey	0.070	3.57	0.25	2.57	0.18
Brazil	0.031	3.54	0.11	2.58	0.08
S. Korean	0.047	3.62	0.17	2.55	0.12
USA	0.045	3.56	0.16	2.44	0.11
Italy	0.105	3.52	0.37	2.57	0.27

Table 4. *Unit power consumption for chosen spinning mill.*

Equipment Type	Number of machines	For unit machine		For total		Share of each in total actual power, %
		Installed power, kW	Actual power, kW	Installed power, kW	Actual power, kW	
Blow Room (Cot-Linen Line)	1	36.00	22.00	36.00	22.00	8.10
Blow Room (Automatic)	1	64.00	42.00	64.00	42.00	
Blow Room (Manuel1)	6	16.30	8.00	97,75	48.00	
Blow Room (Manuel2)	3	7.15	4.00	21,45	12.00	
Blow Room (Poly/vis)	4	26.10	10.75	104,50	43.00	
Vertical Opener	5	9.40	6.00	47.00	30.00	
SUB TOTAL	-	158.95	92.75	370,70	197.00	
Carding M. (Sacolowell)	5	4.00	3.30	20.00	16.50	9.44
Carding M.(C10)	8	13.25	8.50	106.00	68.00	
Carding M.(Rieter)	10	20.70	14.50	207.00	145.00	
SUB TOTAL		37.95	26.30	333.00	229.50	
Drawing Machines	14	10.00	7.50	140.00	105.00	4.30
Combing Machines	4	6.53	5.50	26.12	22.00	0.90
Lap Machine	1	13.00	11.00	13.00	11.00	0.45
Roving Machines	12	17.30	11.40	207.50	136.80	5.60
Ring Spinning Machines	33	40.00	34.00	1320.00	700.00	28.80
Ring Traveler Robots	10	0.497	0.30	4.97	3.00	0.10
Open-end Spinning Machines1	5	81.60	60.00	408.00	300.00	15.10
Open-end Spinning Machines2	1	100.00	67.50	100.00	67.50	
Winding Machine	10	15.50	13.50	155.00	135.00	5.60
SUB TOTAL OF MACHINES				3078.29	1906.80	78.40
Compressor 1	1	58.00	40.00	58.00	40.00	2.63
Compressor2	1	45.00	24.00	45.00	24.00	
SUB TOTAL OF COMPRESSORS		103.00	64.00	103.00	64.00	
Air Conditioning System1	1	110.00	55.00	110.00	55.00	16.00
Air Conditioning System 2	1	147.10	91.00	147.10	91.00	
Air Conditioning System 3	1	147.10	116.00	147.10	116.00	
Air Conditioning System 4	1	126.00	73.00	126.00	73.00	
Air Conditioning System 5	1	81.50	55.00	81.50	55.00	
SUB TOTALOF AİR CONDITIONING		611.70	390.00	611.70	390.00	
LAMPS	2555	0.04	-	102.00	72.00	2.98
TOTAL				3894.99	2432.80	100

sumed energy which formed 78% of the total energy consumption alone.

The chosen spinning mill operated in 3 shifts a day which consisted of 8 hours and also works 25 days a month. Considering the monthly operating time and number of machines, the monthly (May) energy consumption of the chosen spinning mill was calculated and all the data are shown in Table 5. The actual total monthly energy consumption of the spinning mill was 1459680 kWh/month in May as shown. 78.4% of this energy was consumed by the machines, see Figure 1.a and 37% of the monthly energy consumed by the machines was due to the ring spinning machines (Figure 1.b).

In order to determine the unit energy consumption of unit yarn mass which is known as specific energy consumption, the monthly energy consumption of the investigated mill were divided by monthly production quantity and the variation obtained is demonstrated in Figure 2. The amount of specific energy consumption changed between 3.23 and 3.76 kWh/kg in the chosen mill among the selected months. These values were the average which changed depending on the yarn properties.

Determination of energy consumption for chosen yarn

In order to obtain the specific energy consumption of any yarn, a simple approach was developed. Since a manufacturing line contains many steps/machines, the approach is explained here for the first machine which is outlined as the bale opener and the approach should be repeated for the rest of the machine/step. According to this approach, raw material used for each machine should be first found and then the operating time of each machine obtained. Using the operating time and actual power of manufacturing machines, the energy consumption of each machine during manufacturing could easily be calculated [7].

The amount of raw material R_1 (kg) which will be processed in the first machine (bale opener) can be found by using the total waste ratio W_{Tot} (%) and mass of the specific yarn, M (kg) as

$$R_1 = M \times (1 + W_{Tot}) \quad (1)$$

Operating time for the first machine, t_1 (hour), can be determined as follows,

$$t_1 = R_1/(L_1 \times \eta_1 \times n_1) \quad (2)$$

__Table 5.__ Energy consumption for chosen spinning mill in May.

Equipment Type	Hourly energy consumption, kWh	Daily energy consumption, kWh	Monthly energy consumption, kWh
Blow Room (Cot-Linen Line)	22	528.0	13200
Blow Room (Automatic)	42	1008.0	25200
Blow Room (Manuel1)	48	1152.0	28800
Blow Room (Manuel2)	12	288.0	7200
Blow Room (Poly/vis)	43	1032.0	25800
Vertical Opener	30	720.0	18000
SUB TOTAL	197	4728.0	118200
Carding M. (Sacolowell)	16.5	396.0	9900
Carding M.(C10)	68	1632.0	40800
Carding M.(Rieter)	145	3480.0	87000
SUB TOTAL	229.5	5508.0	137700
Drawing Machines	105	2520.0	63000
Combing + Lap Machines	33	792.0	19800
Roving Machines	136.8	3283.2	82080
Ring Spinning Machines + Robots	703	16872.0	421800
Open-end Spinning Machines	367.5	8820.0	220500
Winding Machines	135	3240.0	81000
MACHİNE TOTAL	1906.8	45763.2	1144080
AIR CONDITIONING SYTEMS	390	9360.0	234000
ILLUMINATION	72	1728.0	43200
COMPRESSORS	64	1536.0	38400
TOTAL	**2432.8**	**58387.2**	**1459680**

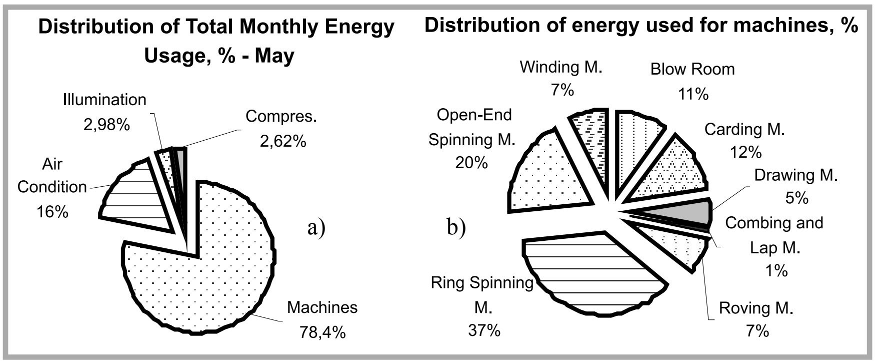

***Figure 1.** Percent distribution of energy consumption in examined spinning mill; a) percent distribution of total energy, b) percent distribution of energy used for machines.*

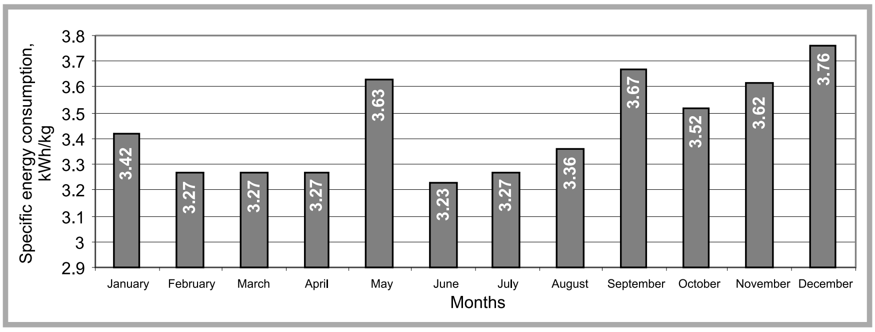

***Figure 2**. Specific monthly energy consumption for spinning mill.*

where; L_1 (kg/h) is the manufacturing rate of the machine, n_1 is the number of machines used and η_1 (%) is the mechanical efficiency of this machine. With given parameters, the electrical energy, E_1 (kWh), used for the first machine can be obtained by

$$E_1 = t_1 \times N_1 \times \eta_{E1} \times n_1 \quad (3)$$

Here, N_1 (kW) is the installed power of the first machine η_{E1} (%) is the energy efficiency concerned. After calculating the energy consumption of each step, the total energy consumed for operating the machines, E_M (kWh), can easily be calculated by the following equation.

$$E_M = \sum_{i=1}^{n} E_i + E_{Ca} + E_D + E_{Co} + E_R + E_S + E_W \quad (4)$$

where E_i is the energy consumption of blow room (E_1; energy for bale opener, E_2; energy for cleaner, E_3; energy for mixer etc.), E_{Ca} is the energy consumption of carding, E_D is the energy consumption of drawing, E_{Co} is the energy consumption of combing, E_R is the energy consumption of roving, E_S is the energy consumption of spinning, E_W is the energy consumption of winding step, *i* represents the relevant individual machine and n is the total number of machines in the blow room.

Energy consumption of compressors for the first machine, E_{A1} is found as

$$E_{A1} = t_1 \times N_A \times C_1 \times n_1 \quad (5)$$

where C_1 (m^3/h) is the compressed air needed per hour, N_A (kWh/m^3) is the unit power for compressors which can be determined by dividing the installed power of the compressor by the compressed air capacity. Total energy consumption for providing compressed air in general, E_{TA} (kWh), is found as $E_{TA} = \sum_{j=1}^{m} E_{Aj}$ and here again *j* represents the relevant machine and *m* is the total number of machines that need compressed air in the production line of specific yarn.

Energy used for air conditioning during yarn production E_C is

$$E_C = E'_C \times M / G \quad (7)$$

where, E'_C expresses the total energy consumption of the air conditioning system in one month while *G* is the monthly yarn production in kg. Similarly, the energy consumption for illumination, E_{il} (kWh) is found as

$$E_{il} = E'_{il} \times M / G \quad (8)$$

Here; E'_{il} is the total monthly energy usage of lamps needed for illumination.

Consequently; the total energy consumption for any specific yarn can be calculated by summing up the relevant energy consumption equations given above as

$$E_{Tot} = E_M + E_{TA} + E_C + E_{il} \quad (9)$$

Prediction of Energy Consumption

The energy consumption for 20 tex (Ne 30) combed ring yarn produced in the spinning mill under investigation was calculated by applying the procedure given above. Here; 3000 kg, 20 tex combed yarn is supposed to be produced in the ring spinning system at a speed of 17500 rev/min and with a twist factor (α_{tex}) of 3828.

Energy consumption for machines and compressed air

The results obtained by the procedure outlined above are demonstrated in Table 6. This contains production parameters (type and number of machines, actual production rate, actual installed power etc.) and calculated data (operating time, energy use for operating machines and compressed air). For the investigated spinning mill, the unit power needed for compressors to provide unit compressed air (N_A) was determined as 0.12 kWh/m^3.

Table 6. *Energy consumption of chosen yarn.*

Machines	Production parameters				Calculated data		
	No of mach.	Actual production rate (l), Kg/h mac.	Actual unit power (n), kW	Unit comp. air needed (c), m^3/h	Operat. time (t), h	Energy for machines (e), kWh	Energy for compr. air (e_a), kWh
Uniflock	1	950	6.00	14.45	4.02	24.12	11.30
Uniclean	1	950	6.75		4.00	27.00	
Unimix	1	617.5	5.25		6.10	32.03	
Uniflex	1	570	9.00		6.60	59.40	
Kondenser	1	570	4.00		6.50	26.00	
Carding M.	4	42.0	14.50	9.10	22.40	1299.20	97.80
Drawing M.	1	181.6	7.50	0.48	20.23	151.73	1.17
Unilap	1	381.5	11.00	3.30	9.60	105.60	3.80
Combing M	3	47.0	5.50	2.40	25.62	422.73	22.10
Drawing M.	1	109.0	8.25	0.56	28.80	237.60	2.00
Roving M.	1	116.6	11.40	0.40	26.73	305.00	1.30
Ring Spin.	3	26.5	34.00	36.25	38.73	3950.50	505.40
Winding M.	1	84.7	13.50	30.00	35.60	480.60	124.60
TOTAL						7121.50	769.47

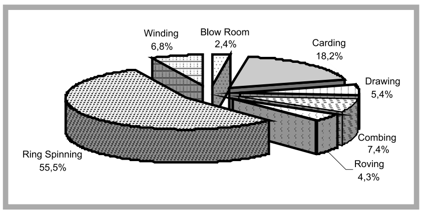

Figure 3. *The share of energy used for machines (%).*

As the machines in the blowing room were interconnected, the compressed air needed has been calculated cumulatively by taking the operating time as 6.6 hours. Using the parameters in the table and related equations, the total energy consumed for machines was found to be 7121.5 kWh and 3950.5 kWh of this was used by the ring spinning machines.

In order to see the percentage of the energy used for each machine, Figure 3 was obtained. As can be seen, the maximum energy consumption (3950.5 kWh) among machines occurred in ring spinning machines (55.5%) and carding machines follow this with a share of 18.2%. This figure also provides the opportunity for comparing the corresponding data with the data available in [23] as shown in Table 7. The calculated share of each machine type in total energy consumption was compared with the results of 10 tex. As the 10 tex yarn is finer than 20 tex, the share of the ring machines for 10 tex yarn seemed to be higher than that of 20 tex, as expected.

Since similar data showing the shares of machines in total energy consumption has not been reached for 20 tex yarn in literature, the energy consumption for 10tex yarn was also calculated by using the present approach with suitable production parameters for 10 tex yarn (α_{tex} = 3828, 16000rpm) and the results were compared with the data in literature [23], as shown in Table 8. The results calculated and data given in literature are nearly the same. The small differences occurring between the values are attributed to the exclusion of the winding step for data in literature and the changes faced in production parameters.

Total energy consumption including air conditioning and illuminating

So as to calculate the total energy usage for the chosen yarn, energy consumption of air conditioning and illuminating should be found, as explained before. For this reason, data such as monthly energy consumption for air conditioning and illuminating system and the amount of monthly yarn production should be obtained. Monthly energy consumption for air conditioning and illuminating were calculated as 234000 kWh/month and 43200 kWh/month respectively, as given in Table 5. And also; it was determined from the mill records that total yarn production was 401580 kg/month for the examined month (May). By application of the developed approach, energy consumption for air conditioning and illumination were found and the results are shown in Table 9.

Specific energy consumption for the yarn concerned was determined as 3.32 kWh/kg which can also be seen from the table. Specific energy consumption for 20 tex combed ring yarn changes between 3.49 and 3.62 kWh/kg among the chosen countries (see Table 3). The data obtained from the present study (3.32 kWh/kg) represents a relatively smaller value than that of the selected countries. It is thought that the difference between the values comes from the changes in manufacturing parameters of machines such as type, waste ratio, speed and energy efficiency.

Energy consumption for different type of yarns

The amount of energy consumption for different types and counts of yarn was calculated in the same way and the results obtained are shown in Table 10.

The finer yarn needs more energy consumption for all types of yarn. Yarns used for weaving involve more twist than yarns used for knitting and production speed is low for weaving yarn and as a result, with the same count more energy is consumed for weaving yarn. Also, for the same count, the energy consumption for combed yarn is higher because of the additional production step (combing). Specific energy consumption of 20 tex combed weaving yarn is recorded as 3.64 kWh/kg whereas; the calculated consumption in the present study takes the value of 3.32 kWh/kg for the same yarn. It appears that the differences in manufacturing parameters cause this discrepancy.

Energy consumption for ring spinning machine

Since the highest energy consumption occurs in spinning machines during yarn manufacturing, many studies have been carried out on the energy consumption of spinning machines. One of the studies shows that specific energy consumption in a ring spinning machine, E_R (kWh/kg), can be calculated with the equation given below [16].

$$E_R = 106.7 \times F^{-1.482} \times D_r^{3.343} \times \times n^{0.917} \times \alpha_{text}^{0.993} \quad (10)$$

Here; F is the linear density of yarn (tex), D_r is the diameter of ring (m), n is the speed of spindle (1000 r.p.m.) and α_{text} is the twist factor of the yarn. The production parameters of 20 tex combed yarn of which the total energy consumption is calculated in the present study are n = 17500 r.p.m., α_{text} = 3828

Table 7. *Comparison of energy consumption.*

Machines	The Share of Energy Consupmtion for Each Machine (%)	
	10tex (Literature)[23]	20tex (Present Approach)
Blowing Room	3.37	2.4
Carding	6.52	18.2
Combing	3.52	7.4
Drawing	2.09	5.5
Roving	5.77	4.3
Ring Spinning	78.73	55.4
Winding	-	6.8
TOTAL	100	100

Table 8*. Comparison of energy share of machines for 10tex yarn.*

Machines	Production Parameters			Calculated Data for 10tex		Machines	Calculated energy share for machines, %	Data in literature for 10 tex, % (23)
	No of mach.	Actual production rate (L), kg/h mac.	Actual unit power, (N), kW	Operat. Time (t), hour	Energy for machines (E), kWh			
Uniflock	1	950.00	6.00	4.02	24.14	Blowing Room	1.1	3.37
Uniclean	1	950.00	6.75	4.00	27.00			
Unimix	1	617.50	5.25	6.10	32.03			
Uniflex	1	570.00	9.00	6.60	59.40			
Kondenser	1	570.00	4.00	6.50	26.00			
Carding M.	4	38.84	14.50	23.78	1378.95			
Drawing M.	1	167.65	7.50	21.90	164.25			
Unilap	1	381.15	11.00	9.60	105.60	Carding	8.5	6.52
Combing M	3	43.40	5.50	27.76	458.15	Combing	3.5	3.52
Drawing M.	1	100.61	8.25	31.24	257.73	Drawing	2.6	2.09
Roving M.	1	72.88	11.40	42.80	487.92	Roving	3.0	5.77
Ring Spin.	9	8.56	34.00	39.95	1222.40	Ring Spinning	75.8	78.73
Winding M.	2	45.65	13.50	33.02	892.35	Winding	5.5	-
TOTAL					16139.90	TOTAL	100.0	100.00

Table 9. *Total energy consumption for chosen yarn.*

Consumption place	Energy consumption, kWh	Share, %	Specific energy consumption, kWh/kg
Machines	7121.5	71.3	
Compressors	769.5	7.7	
Illumination	322.7	3.5	$\frac{9961.7}{3000} = 3.32$
Air Conditioning	1748.0	17.5	
TOTAL	9961.7	100.0	

Table 10. *Specific energy consumption for chosen yarns [10].*

Yarn count, tex	Specific energy consumption for chosen yarns, kWh/kg			
	Combed		Carded	
	Knitting	Weaving	Knitting	Weaving
37	1,38	1,63	1,34	1,62
33	1,58	1,88	1,54	1,86
30	1,79	2,12	1,73	2,09
25	2,19	2,60	2,11	2,55
20	3,06	3,64	2,96	3,57
17	3,89	4,62	3,74	4,53
15	4,42	5,25	4,23	5,12
12	5,52	6,81	5,52	6,72

(α_e = 4) and D_r = 0.04 m. If these parameters are evaluated in the equation (10), the specific energy consumption of ring machines is found as 1.36 kWh/kg. As can be seen from Table 8, the total energy consumption of ring machines during manufacturing was calculated as 3950.5 kWh with the present approach. If the total consumption is divided by production amount, the specific consumption is obtained as 1.32 kWh/kg and this value seems to be 3% lower than that obtained by the equation (10). The difference between these two values is attributed to the difference detected in parameters such as speed, waste ratio, mechanical efficiency and energy loss of ring spinning machines.

Summary

As a result of detailed investigations into energy consumption for yarn manufacturing with special reference to ring spinning, important findings are summarised below.

1. It was shown that the manufacturing machines consume 72% of the total monthly energy consumption (1459680 kWh/month) while air conditioning comprises 16% of the total energy consumption in the chosen spinning mill. Additionally, specific energy consumed for each month in a one-year period was calculated and it was determined that the calculated values change between 3.23 and 3.76 kWh/kg.

2. With the simple model developed, the total energy consumed during the manufacturing of 100% cotton, 20 tex combed ring spun yarn in the chosen spinning mill, was calculated as 9961.7 kWh, 71.3% of which was consumed by manufacturing machines. The highest energy consumption with 55.5% share occurred in spinning machines alone. The values calculated were compared with the data available in the literature and it was shown that there was a close agreement between calculated data and data given in literature. The small differences were attributed to differences in operation parameters such as type, mechanical efficiency, energy loss and waste ratio of machines.

3. The specific energy consumption for 20 tex combed ring yarn was obtained as 3.32 kWh/kg and this value was compared with the values outlined by ITMF (changing between 3.49 and 3.62 kWh/kg for the same yarn type). The difference between calculated and reported values is thought to be because of the difference in production parameters.

4. The specific energy consumption of the ring spinning machine during the chosen yarn production, was calculated as 1.32 kWh/kg by the given approach, while this value was obtained as 1.36 kWh/kg by the equation given in literature. There seemed to be 3% percentage difference between the calculated value and data taken from literature.

5. It has been demonstrated that the approach given in this study can be used to calculate the total and specific energy consumption of a particular type yarn with reasonable confidence.

References

1. *Kornreich E.; Introduction to Fibers and Fabrics-Their Manufacture and Properties, Second Edition England: Seven Corners Press; 1966.*
2. *Lawrence C. A.; Fundamentals of Spun Yarn Technology, New York: CRC Press; 2003.*
3. *Lord P. R.; Hand Book of Yarn Production Technology Science and Economics, The Textile Institute, United Kingdom :Cambridge Woodhead Publishing; 2003.*
4. *Grosberg P., Iype C.; Yarn Production-Theortical Aspects, United Kingdom: The Textile Institute; 1999.*
5. *McCreight D. J., Feil R. W., Booterbaugh J. H., Backe, E. E.; Short Staple Yarn Manufacturing, North Carolina: Carolina Academic Press; 1997.*
6. *Oxtoby E.; Spun Yarn Technology, London: Butterworth & Co Publishers; 1987.*
7. *Kaplan E.; The Cost Factor in Textile Industry and General Utilization of Energy Cost, MsC Thesis, Cukurova University, Institute of Natural and Applied Science, Textile Engineering Department, Adana 2004 (in Turkish).*
8. *ITMF, International Comparison of Manufacturing Costs, Spinning/Weaving/Knitting, Sweden: International Textile Manufacturers Federation; 2003.*
9. *Kuşçuoğlu R.; Analysis of Turkish Textile And Clothing Sectors, MsC Thesis, Cukurova University, Institute of Natural and Applied Science, Textile Engineering Department, Adana, 2002 (in Turkish).*
10. *Koç E, Kuşçuoğlu, R., Spinning Yarn Production Costs in Open-End and Ring Systems, Textile Technology, 2004; Number 100: pp. 122-134 (in Turkish).*
11. *Koç E., Kuşçuoğlu R., Factors that Affect Labor and Energy Costs in Yarn Production-Ring Spun Yarn Production, Textile Technology, No. 103 (2005) pp. 160-169 (in Turkish).*
12. *Örtlek, H.G., Şener, M., Ülkü., Ş., Production Cost Analysis of MVS Yarns and Comparison With the Conventional Spinning Systems, Textile Technology, 2004; August: pp. 82-92 (in Turkish).*
13. *Anonymus; Output of a Seminar on Energy Conservation in Textile Industry, Malesia: 1992; www.unido.org/userfiles/PuffK/textile.pdf.*
14. *Tarakçıoğlu I.; Energy Consumption and Conservation of Textile Finishing Mills, Bursa:Uludag University Press; 1984. (in Turkish).*
15. *Kim S. Y., Grady P. L., Hersh S. P.; Energy Consumption and Conservation in the Fibre-producing and Textile Industries, The Textile Institute Vol. 13, No. 3, 1983.*
16. *Krause H. W., Soliman H. A.; Energy Consumption of Rotor Type OE-Spinning Machines as Compared to Ring Spinning Frame. International Textile Bulletin, 1982; Third Quarter: pp. 285-303.*
17. *Ye G.; Calculation of Power Consumption of Bare Spindle (Without Bobbin) for Ring Spindle. Journal of China Textile University, English Edition, Vol. 13, No. 2 (1996) pp. 62-66.*
18. *Tang Z. X., Wang Z., Fraser B.; Distribution of Power Requirements During Yarn Winding in Ring Spinning. Textile Research Journal, Vol. 74 (2004) pp. 735-741.*
19. *Tang Z. X., Wang Z., Fraser B.; Energy Consumption Per Unit Yarn Production in Ring Spinning. Proceedings of the Sixth Engineering Mathematics and Applications Conference, EMAC 2003 Proceedings, UTS Printing Services: 2003; pp. 289-294.*
20. *Tang, Z. X., Wang, Z. and Fraser, B., Minimizing Energy Consumption of Yarn Winding Ring Spinning. Textile Research Journal, Vol. 74 (2004) pp. 1097-1103.*
21. *Chang L., Tang Z. X., Wang X.; Effect of yarn hairiness on energy consumption in rotating a ring-spun yarn package. Textile Research Journal Vol. 73 No. 11 (2003) pp. 949-954.*
22. *DİE, Energy Consumption in the Manufacturing Industry (Establishments with 500 Tons of Oil Equivalent or More Energy Consumption) 1999-2001, Ankara: State Institute of Statistics Prime Ministry Republic of Turkey, 2004; No. 2916.*
23. *Bozkurt Y., Energy Consumption and Conservation in Conventional Yarn Manufacturing, Seminar Notes about Energy Consumption and Conservation in Textile Mills, Bursa: Sümerbank Textile Education and Research Institute, 1985; No. 77 (in Turkish).*

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IW INSTYTUT WŁÓKIENNICTWA
Textile Research Institute

Since July 1st, 2007 according to the Decision of the Polish Minister of Economy of June 20th, 2007 (published in: Journal of Laws of 2007, no.115, item 799)

- Institute of **Textile Architecture** (Instytut Architektury Tekstyliów – IAT)
- Institute of **Textile Materials Engineering** (Instytut Inżynierii Materiałów Włókienniczych)
- 'Tricotextil' **Institute of Knitting Techniques and Technologies** (Instytut Technik i Technologii Dziewiarskich Tricotextil)

have been almagamated with the **Textile Research Institute** (Instytut Włókiennictwa – IW).

Pursuant to paragraph 6.1, point 3 of this Decision, Textile Research Institute enters into all the rights and obligations which were the subject of the included institutions despite their legal characteristics.

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Deputy Director for R&D: Mrs Jadwiga Sójka-Ledakowicz Ph.D., Eng.

The consolidated Institute combines traditions and experience of four institutions specialising in different areas of textiles.

Currently, at our disposal we have considerable **R&D potential**:

- 128 research workers
- 10 accredited testing laboratories (testing and certification of textile materials)
- The Institute is a notified body within 3 EU Directives:
  - 88/378/EEC/ The Directive on the Safety of Toys,
  - 89/686/EEC/ The Directive on Personal Protective Equipment (PPE)
  - 93/42/EEC/ The Directive on Medical Devices
- The Institute is the coordinator of 2 scientific networks:
  - TEXMEDECO NET – International Scientific Network Textiles and Health
  - INTRANANOTEX – Nanotechnologies in textile industry

Our Institute acting as a supporting partner for the textile industry has been carrying out R&D work in the areas of :
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- polymers,
- textile chemistry,
- biotechnology,
- environmental protection,
- textile techniques and technologies.

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- health protection
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- innovative goods - high-tech products of special properties and for new application fields
- functional textile products - barrier products - added value textiles, smart textiles,
- biomaterials.

An **interdisciplinary approach** is necessary to develop the technologies of producing such textile materials. We are open to cooperation and welcome potential partners willing to search for new ideas in textiles.

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