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Thermodynamics and life span estimation

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ABSTRACT

In this study, the life span of people living in seven regions of Turkey is estimated by applying the first and second laws of thermodynamics to the human body. The people living in different regions of Turkey have different food habits. The first and second laws of thermodynamics are used to calculate the entropy generation rate per unit mass of a human due to the food habits. The lifetime entropy generation per unit mass of a human was previously found statistically. The two entropy generations, lifetime entropy generation and entropy generation rate, enable one to determine the life span of people living in seven regions of Turkey with different food habits. In order to estimate the life span, some statistics of Turkish Statistical Institute regarding the food habits of the people living in seven regions of Turkey are used. The life spans of people that live in Central Anatolia and Eastern Anatolia regions are the longest and shortest, respectively. Generally, the following inequality regarding the life span of people living in seven regions of Turkey is found:

Eastern Anatolia < Southeast Anatolia < Black Sea < Mediterranean < Marmara < Aegean < Central Anatolia.

1. Introduction

The life span of living organisms, particularly human beings, has always been of interest. Consequently, various methods have been used to estimate the life span of human beings. Among these methods, entropy generation of a human is a method to determine the life span. Living organisms, as a known reality, require energy, in the form of both heat and work in terminology of thermodynamics, to sustain their life. Living organisms use heat and work for functioning activities such as walking, repairing or restoring the cells, keeping the temperature of body at a constant level and so on. The only resource to meet these requirements is the foods that are eaten.

The foods, in general, are composed of carbohydrate, fat and protein. Living organisms consume air that contains oxygen necessary for reaction with carbohydrate, fat and protein. These reactions produce both heat and work for being able to function the essential activities of living organisms. Work, in a human body, is produced and stored in the form of ATP molecules. If a human body is to be assumed as a heat engine, its efficiency in conversion of heat to work is around 25–30% [1]. A human body can be considered as a thermodynamic system. A system may exchange heat or work or both with its surroundings. Work exchange does not produce entropy, but heat does. The reaction of foods with oxygen produces heat which is an irreversible process. Since heat production is an irreversible process, it always happens along with entropy generation. Therefore it can be stated that a human produces entropy as long as foods are consumed.

The stored fat and etc in human body, as sources of entropy production, are neglected. Therefore, a human does not produce entropy when foods are not consumed. In brief, a human produces entropy as long as he is alive. This fact enables one to calculate the entropy generation rate of a human caused by heat production as a result of nutrition. The lifetime entropy generations of a large number of humans are considered and therefore, an average lifetime entropy generation per unit mass is obtained. The average lifetime entropy generation per unit mass is assumed to be constant for each human being. Therefore, the life span of a human can be determined by dividing the average lifetime entropy generation per unit mass by the entropy generation rate per unit mass.

In the following, the investigators who have used the entropy generation method to determine the life span of a human are explained.

Silva and Annamalai [2,3] have applied the first and second laws of thermodynamics to human body. They have found that the average lifetime entropy generation per unit mass of human beings

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Nomenclature

Q	heat transfer, kJ
W	work transfer, kJ
H	total enthalpy, kJ
n	mole number
$\bar{h}_f^0$	formation enthalpy, kJ/kmol
$\bar{h}$	enthalpy at given temperature, kJ/kmol
$\bar{h}^0$	enthalpy at standard condition, kJ/kmol
T	temperature, °C or K
S	total entropy, kJ/K
Greek symbols	
Δ	difference
η	efficiency
Subscripts	
env	environment
gen	generation
i	inlet
o	outlet
p	products of combustion
r	reactants of combustion
sys	system

is 11,404 kJ/kg K. The average lifetime entropy generation amount and the data for food consumption in USA are used and therefore, the life spans of men and women in this work are found to be 73.78 and 81.61 years, respectively. The effect of different diets on life span is explored, too.

The BMC (basal metabolic rate) shows the rate (velocity) of reaction of foods with oxygen. The rates of reaction in different conditions, for example a human at rest, exercise, youth, old age, illness, good health etc are different. Among these different conditions, the rest condition is long-continued in human life therefore, the rest condition is chosen as the basis for most works. Hershey and Wang [4] have taken the Basal Metabolic Rate related with the rest condition in their work. According to this assumption, they have found that the lifetime entropy generations per unit mass of men and women are 10,025 kJ/kg K and 10,678 kJ/kg K, respectively.

Hershey [5] in his book has expressed that the Basal Metabolic Rate declines slightly as humans get older. If the Basal Metabolic Rate and the air amount used during the life of a human are known, the lifetime entropy generation can be found. These data are used and the lifetime entropy generations per unit mass of men and women are found to be approximately 2395 kcal/kg K and 2551 kcal/kg K, respectively. These amounts in SI unit system correspond to 10,027 kJ/kg K for men and 10,680 kJ/kg K for women (1 cal = 4.1868 J). The amounts of lifetime entropy generation are used and the potential life spans for men and women are found to be 84 and 96 years, respectively. Hershey [5] expresses that, according to some investigators, when the Basal Metabolic Rate decreases to a known minimum, life ends. In the last moments of life the critical Basal Metabolic Rate per unit mass of men is 0.84 kcal/kg h (or 3.52 kJ/kg h). In other words, when the Basal Metabolic Rate decreases to 0.84 kcal/kg h, life ends. By using the amount of critical Basal Metabolic Rate, the critical entropy generation rates per unit mass of men and women in the last moments of life are found to be 0.00269 and 0.00260 kcal/kg h K, respectively. These amounts in SI unit system correspond to 0.01126 kJ/kg h K for men and 0.01089 kJ/kg h K for women.

Aoki [6] has given the entropy generation at different ages of a human. However, he has not given the lifetime entropy generation. Silva and Annamalai [2] have used extrapolation approach and have found that the lifetime entropy generation, according to the data given by Aoki [6], corresponds approximately to 8000 kJ/kg K.

Rahman [7] has calculated the entropy generation by taking into account the entropy fluxes to and from a human body. Rahman [7] has considered the effects of mass fluxes to and from a human body, convection to or from a human body surface, heat loss induced from evaporation from human skin and activity level of human (rest, exercise, etc) and clothing on the entropy generation. He has found the entropy generation rates at rest, exercise and death equal to 21×10^{-5} kW/K, 219×10^{-5} kW/K and 0 kW/K, respectively. The entropy generation rate in the present study is approximately 50% in excess of that of Rahman [7]. The comparison is done with the assumption that human is at a rest condition during the whole life.

Annamalai and Puri [8] have applied the first and second laws of thermodynamics to the human body and thereby, the average lifetime entropy generation per unit mass was found to be 10,000 kJ/kg K. By using this data, the life span of human beings was calculated 77 years.

Kuddusi [9] studied the human body by the point of view of the first and second laws of thermodynamics. The investigator took into account the typical glucose consumption of a human and its oxidation. The entropy generation rate per unit mass of a human induced from this exothermic reaction is calculated as 0.41×10^{-5} kW/kg K. The average lifetime entropy generation found by Annamalai and Puri [8] is used by Kuddusi [9] in her work. Thereafter, she has estimated the life span of human beings to be 77.34 years.

Aoki [10] calculated the entropy that enters to and exits from a human by means of radiation, convection, evaporation from the skin and mass transfer. Consequently, he evaluated the human body net entropy flow by knowing the entropy that enters to and exits from a human. He also estimated the change in entropy of a human. The change in entropy minus the net entropy flow would give the entropy generation of a human. The investigator claims that environmental conditions such as temperature, clothing and air velocity have almost no effect in the entropy generation. Accordingly, he found the average entropy generation of a human in the amount of 0.172 W/m^2 K.

Aoki [11] explored the effect of exercise on entropy generation of a human, too.

Aoki [12] in another work concerns the three stages of a human categorized as childhood, youth and old age. The entropy generation rates in each stage are different. In this work Aoki [12] claims that 98.6% of the total entropy generation comes from the metabolic entropy generation which is sustained when the human is at rest. He claims also that the entropy generation in women is 8.7% less than that of men averagely. On average, Aoki [12], with a suspicion, believes that the entropy generation for men and women does not reduce to a minimum or to a known level during their life.

Aoki published a book in 2012 and applied the laws of thermodynamics to bio-systems in general. The sections of this book are in Aoki [13–21]. In this book, Aoki [13–21] states that the entropy generation in a human first increases and then decreases till death. That is, the entropy generation has a maximum in the life and a lowest value at the end of life. The author of the present study believes that the lowest value is not the same constant for different humans.

The above mentioned works, particularly the life span estimations, are valid for the people of USA and Japan. A work that estimates the life span of people living in Turkey is not done yet. In the