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Original Article

Study and Investigation of Heat Storage Materials for Solar Cooker

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Abstract - *Today, energy storage solutions play a crucial role in managing the increasing energy demands and enhancing the efficiency of solar-based devices. These demands are constantly rising in various sectors, such as households, manufacturing companies, and other utility areas. Renewable energy sources fulfill some of these demands, but certain limitations, such as constant and continuous availability, have created several challenges. To overcome this challenge, energy storage systems have emerged as a viable solution. These materials store the energy when available and release it when needed, following the latent and sensible heat capacity concept. Traditional thermal energy storage materials, like paraffin wax, oil, pebbles, etc., have been extensively used in many applications. The present work provides a detailed experimental study of innovative and new materials like beeswax, steel, gritty, scrappy iron, scrappy aluminum, sand, ceramic, granite stone, brass, and combinations to take advantage of latent and sensible storage. A unique experimental setup has been designed and developed to test these materials from the energy storage point of view. It is observed that heat storage can be enhanced by 43 % by selecting appropriate storage materials. Beeswax with Granite Stone mixture is efficient for heat storage for night cooking. This innovation represents a significant advancement in maintaining the efficiency and performance of solar-based applications.*

Keywords - *PCM, latent heat, Sensible heat, Insulation material, Heat drop box, Solar energy.*

1. Introduction

It is understood that energy cannot be created or destroyed; rather, it can only be changed from one form to another, but there is a necessity for it to be stored. Today, the essentiality of energy storage for various household applications such as space heating, evening cooking, water heating, food preparation, and food preservation is recognized. Numerous energy sources, including Solar Energy (SE), Tidal Energy (TE), Geothermal Energy (GE), and Wind Energy (WE), are found on Earth. Among these, solar energy is noted for its cost-effectiveness, pollution-free nature, ready availability, and abundance, making it one of the most promising alternative energy options [1].

Energy can be stored in three primary ways: Thermal Energy Storage (TES), Electrical Energy Storage (EES), and Mechanical Energy Storage (MES). In this discussion, emphasis will be placed on thermal energy storage, particularly in the context of solar energy. The objective is to develop a unique solar cooker designed for nighttime cooking. In conjunction, a specialized heat storage unit will be created to store solar energy for later use efficiently.

Phase Change Materials (PCMs) have been identified as pivotal components in Thermal Energy Storage (TES) systems, drawing significant attention in research over the past two decades [2]. The ongoing challenge posed by escalating energy demands across various sectors, including residential, industrial, and commercial applications, has prompted the exploration of solutions. Renewable energy sources are increasingly being utilized to meet these demands, yet their intermittent nature necessitates alternative means of stabilization, such as TES systems [26]. The performance of application apparatuses is enhanced by the unique characteristics inherent in TES [3]. These attributes bolster the efficiency of solar-based applications and contribute to overall performance enhancements. The fundamental processes underlying energy storage encompass cooling, melting, solidifying, heating, and vaporizing, each resulting in energy release upon reversal [4]. Energy is stored in two primary forms: Sensible Heat Storage (SHS) and Latent Heat Storage (LHS). SHS involves materials undergoing temperature variations based on their specific heat capacity, resulting in either temperature increase or decrease. Conversely, LHS entails phase transitions, such as solid to liquid (S-L) and liquid to vapor (L-V), without affecting the material's temperature [4]. In summary, TES, particularly employing PCMs, has become indispensable in addressing the escalating energy demands by providing reliable and efficient solutions, thereby ensuring a stable energy supply despite fluctuations in renewable energy sources.

1.1. Literature Review

N.M. Nahar [5] developed a double-walled hot box and it is filled with engine oil. He has found that HBSC efficiency is 27.5%. Pinar Mert Cuce [6] used Bayburt stone for heat storage in a cooker. He has found that Bayburt stone is capable of heat storage at night cooking.

Mahavar et al. [7] presented SC for a solo family. They found the highest temperature cooking pot, initial cooking power, and the quantity of heat loss at 144°C, 03.5 W, and 1.474 W/°C, respectively.

Zamani et al. [8] planned and created an SC linked to parabolic glasses. They found that the optimized position of the glasses was suitable for cooking. Vikrant Yadav et al. [9] used commercial-grade acetamide with Sand, iron grits, stone pebbles, and iron balls. They found that grits and stones are not suitable, and pebbles and iron balls are suitable for heat storage for cooking.

Avinash Chaudhary et al. [10] tested a solar cooker with an outer surface painted black and a solar cooker with an outer surface painted black along with glazing, and they found that black along with glazing is best.

1.2. Research Gap

Previous research has explored various enhancements in solar cookers, such as integrating auto-tracking systems to improve performance and utilizing solid materials and Phase Change Materials (PCMs) for heat storage individually. However, there remains a significant gap in the literature regarding the combined use of sensible heat storage materials and latent heat storage materials in solar cookers. Additionally, while heat storage systems have been developed for other applications, there is limited investigation into their adaptation, specifically for cooking purposes. Therefore, this paper aims to introduce a novel heat storage mixture designed for solar cookers, combining both sensible and latent heat storage capabilities. Furthermore, it proposes the development of a heat preservation box optimized for nighttime cooking scenarios. These innovations seek to address the current gaps in research by enhancing the efficiency and practicality of solar cooking solutions through advanced heat storage technologies.

2. Methodology and Experimentation

After the solar cooker was designed, a significant challenge was encountered in this research: how to effectively store the harvested energy. A highly efficient solution, comprising a heat preserves box and a unique cooking pot, was innovatively developed to address this issue.

2.1. Design and Specification of Heat Preserve Box

An innovative design has been implemented to ensure heat retention for extended periods, guaranteeing a sustainable energy source for night cooking. Constructed from sturdy plywood and covered with a sun mica sheet, the insulated heat drop box features hollow sections between two layers of plywood, which have been carefully filled with insulating glass wool. This design effectively preserves heat and facilitates convenient and reliable nighttime cooking, marking a crucial advancement in solar energy utilization.

Table 1. Heat preserves box specification

Specification	Reason for selection of specification
Outer box Size: 60 × 60 × 36 cm	Outer box size depends on the inner box size and insulation space. Here, 8 cm space is used for insulation material, which reduces heat loss.
Inner Box Size: 42 × 42 × 24 cm	As per the cooking pot specification
Door Size: 60 × 60 × 6 cm	As per outer and inner box dimensions.
Basic Material of Box: Plywood	It is cheap, easily available, and low weight with enough hardness.
Insulation Material: Glass wool	Low weight, low cost, and good hit blocker.
Insulation Material weight: Appx. 3 to 4 kg	As per insulation space
Sun mica sheet collar: White	High heat waves reflected color.
Weight: 17 Kg max	According to the used materials
Shape: Square	Easy manufacturing
Handle: Steel handle	Easy loading and unloading
Tracking: Manually with four castor wheels	Easy tracking
Finish: Attractive with safety.	For safe using
Storing Cooking pot Capacity: 8- 10 litter	A vessel with a cooking capacity of 1.5 litres is required to cook enough for a small family, but to provide the heat needed to cook as much as the hit requires about 5 to 6 Kg of LHSM to place the cooking port.

Heat is naturally transferred from high-temperature to low-temperature areas, resulting in continuous heat loss from the heat sink, as demonstrated by the cooking pot heat sink. Excessive heat flow from the cooking vessel must be regulated to enable nighttime cooking. The outer box of the heat sink, measuring 60 × 60 × 36 cm, houses an inner box of 42 × 42 × 24 cm, which is constructed from 10 mm plywood with white sun mica. 4 kg of glass wool is placed between the inner and outer boxes for adequate insulation. The square-shaped design simplifies manufacturing and is complemented by four castor wheels for easy mobility, along with a steel handle for convenient loading and unloading. Detailed specifications and rationale for choosing this insulated heat preserve box are outlined in Table 1. Additionally, it is a 3D model (Figure 1).

2.2. Design and Specification Cooking Pot

A unique cooking pot for cooking is developed only for heat storage. Aluminum was selected as the material for the cooking pot due to its higher thermal conductivity. The pot has dimensions of 15 cm × 35 cm × 3 mm thickness and a storage capacity of 6 liters. A commercial pressure cooker was purchased for cooking, with dimensions of 12 cm × 13 cm × 3 mm thickness and a capacity of 1.5 liters. A 127 mm size hole was provided on the top side of the pot, and a 3 mm thick rubber seal was placed around the periphery of the hole to prevent heat loss during cooking, where the commercial pressure cooker is placed. The specification of the cooking pot and the reason for its selection are shown in Table 2, and the unique cooking pot (See Figure 2).

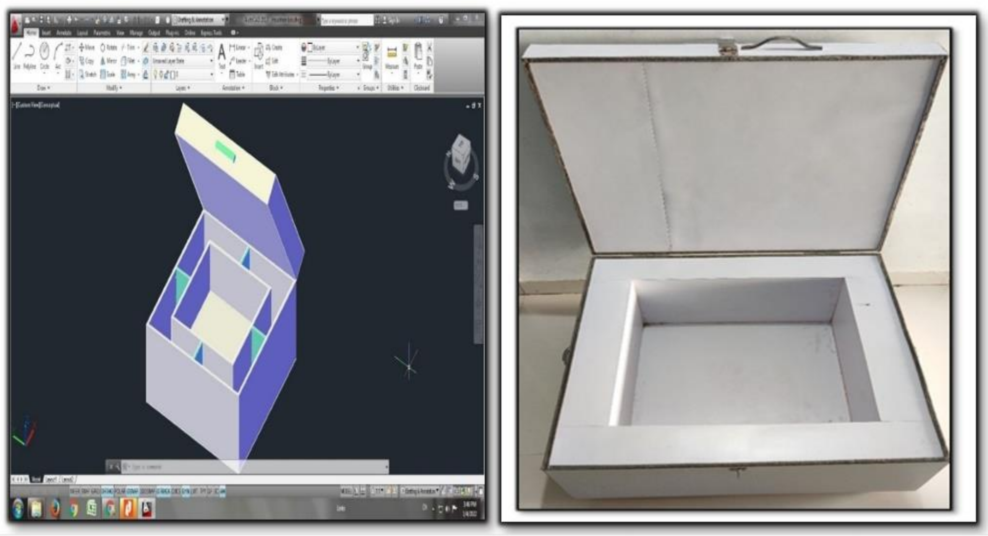

Fig. 1 Developed insulation heat preserve box

Table 2. Cooking pot specification

Specification	Reason for selection of specification
Unique cooking pot Material: Aluminium	low cost and easily available in the market.
Outer size is 15 cm × 35 cm × 3 mm thickness	The outer box size depends on the inner box size and the heat storage material used.
Cooking vessel size is 12 cm × 13 cm × 3 mm thickness	As per the literature survey, 1.5 litters are required for cooking in a single family.
Outer vessel capacity: 6 to 7 Kg max.	As per research reviews, five litter cookers have a maximum capacity for cooking meals for a single family (8 to 10 members).
Inner vessel capacity: 1.5 Kg max.	As per the literature survey, 1.5-litre cookers are required for cooking in small families.
Thermocouple: K-type	Easily available, easily operated, and non-hazardous for the human body and cooking food.
Door	It reduced the heat loss.
8-series meter	Storage the temperature reading.
Latent heat storage material: beeswax	Easily available, Low-cost, non-hazardous for the human body and cooking food.
Sensible heat storage material	Easily available, Low-cost, non-hazardous for the human body and cooking food.

3. Study Area

In this paper, it was found that the best heat storage mixture was identified for night cooking. Many common materials are readily available at home were utilized, such as beeswax as a latent heat storage material and steel (bolt, boll, and roller), gritty (20 mm and 40 mm), scrappy iron, scrappy aluminum, sand, ceramic (Vitrified tiles), granite stone (black), and brass as sensible heat storage materials (See Figure 3).

Fig. 2 Developed cooking pot

Fig. 3 Testing material (1) Granite stone, (2) Gritty 40 mm, (3) Vitrify tiles, (4) Alloy steel bolts, (5) Scrappy iron, (6) Alloy steel balls and rollers, (7) Scrappy aluminum, (8) Gritty 20 mm, (9) Brass, and (10) River sand.

Table 3 displays the selected material's specific heat capacity, melting point, and thermal conductivity. A combination of 5 kg of beeswax and 2 kg of various sensible heat storage materials is employed based on the specific heat capacity and weight of cooked food (rice, a common choice) for a single family.

Two temperature readings are taken for all tests conducted on the cooking pot (one closer to the top and another closer to the bottom) every half hour for a duration of up to 6 hours from the initiation of the experiment. The whole setup of the experiment (See Figure 4).

Fig. 4 Full setup of the experiment

The average temperature of the mixture is subsequently determined. All readings are provided in ANNEXURE-1, while the average temperature of various mixtures over 6 hours is tabulated in Table 4 and Table 5. Temperature readings are recorded every half hour using K-type thermocouples to sense the temperature, and the data are stored using 8-series meters in microchips.

All mixtures are initially heated to 90 degrees Celsius to ensure uniformity in readings. Each reading is taken in duplicate simultaneously, with one pot placed in a developed heat-preserving box and the other in an open environment to assess the performance of the developed heat-preserving box.

The tests were conducted diligently from December 24, 2022, to January 10, 2023, within the confines of the homeroom at "Sudharm," situated in Ratanpar, Surendranagar, Gujarat, India, eliminating any influence of wind speed during the testing process.

Table 3. Properties of selected material

Name of Material/ Properties	Bees Wax	Steel Bolts	Alloy Steel Bolls & Rollers	Aluminium	Gritty 40 mm	Gritty 20 mm	Granite Stone	Sand	Vitrified tiles	Iron	Brass
Specific heat capacity (J/g-°C)	3.4	0.500	0.475	0.9	0.88	0.88	0.210 - 0.350	0.753	0.323 - 0.326	0.44	0.38
Melting point °C	62 - 65	1400 - 1450	1424	660	1200	1200	1215 - 1260	1700	>1200	1535	990 - 1025
Thermal conductivity (W/m-K)	0.25	16.3	46.6	235	1.40 - 1.80	1.40 - 1.80	1.20 - 4.20	0.3347	1.25 - 1.43	76.2	159

Table 4. Temperature reading when pot put in insulated heat preserve box

Time (hr)	Bees Wax	Steel Bolts	Alloy Steel Bolls & Rollers	Aluminium	Gritty 40 mm	Gritty 20 mm	Granite Stone	Sand	Vitrified tiles	Iron	Brass
1	75	87	85	89	86	88	89	87	86	87	88
1.5	68	82	81	87	82	86	87	82	83	84	80
2	63	77	78	85	79	85	86	79	80	81	75
2.5	59	75	76	82	76	84	85	75	77	78	71
3	57	72	75	80	72	83	84	73	75	75	67
3.5	56	70	73	78	71	82	82	71	72	71	64
4	56	68	70	75	69	80	77	68	71	67	62
4.5	55	65	68	70	67	75	73	65	67	64	60
5	55	62	65	66	66	71	71	64	65	63	58
5.5	53	60	61	63	65	69	69	63	64	62	55
6	51	57	58	60	64	68	67	62	62	60	53

Table 5. Temperature reading when pot put in open air

Time (hr)	Bees Wax	Steel Bolts	Alloy Steel Bolls & Rollers	Aluminium	Gritty 40 mm	Gritty 20 mm	Granite Stone	Sand	Vitrified tiles	Iron	Brass
1	64	65	63	66	64	62	63	61	60	62	65
1.5	52	59	58	63	59	56	58	52	53	55	56
2	50	46	48	57	51	54	57	49	49	51	46
2.5	48	43	46	52	46	53	55	44	46	47	41
3	45	40	44	50	42	52	53	41	43	43	37
3.5	41	40	43	47	41	51	52	41	42	41	37
4	38	37	40	46	40	50	49	40	41	40	35
4.5	36	36	40	41	39	50	48	40	40	39	33
5	34	34	38	38	39	46	46	37	38	37	32
5.5	33	34	35	36	38	43	44	37	37	37	31
6	32	33	33	35	38	39	40	34	36	34	30

Based on the average temperature of the mixture, it was determined that the mixture was heated for night cooking. The mixture was checked in three ways based on the average temperature to determine which mixture could be stored for a long time and used for dinner preparation.

- It was found that the mixture maintaining a temperature above 60 degrees Celsius even after 6 hours was deemed the best for night cooking.
- According to Newton's law of cooling, the mixture with the least cooling rate after 6 hours was considered best for night cooking, as shown in Equation (1).

$$-dT/dt = k(Tt - Ts) \qquad (1)$$

$$k = -\frac{dT}{dt} * 1/(Tt - Ts) \qquad (2)$$

The constant "K" of Newton's cooling law was checked by MATLAB software (as presented in ANNEXURE-2) to determine the best mixture during heat retention time.

4. Result and Discussion

From December 24, 2022, to January 10, 2023, testing was conducted on 11 materials for storing heat for night cooking. Beeswax was mixed with steel bolts, alloy steel balls, rollers, aluminium, gritty 40 mm, gritty 20 mm, granite stone, sand, vitrified tiles, iron, and brass, all commonly found around the house. Readings were taken using beeswax alone and 5 kg of beeswax with 2 kg of each other material used for the readings.

Based on the test readings, it was observed that (1) after 6 hours, temperatures of 51, 57, 58, 60, 64, 68, 67, 62, 62, 60, and 53 degrees Celsius were maintained by the mixture of beeswax, steel bolts, alloy steel balls, and rollers, aluminium, gritty 40 mm, gritty 20 mm, granite stone, sand, vitrified tiles, iron, and brass respectively when placed in an insulated wooden base heat preserve box temperatures of 32, 33, 33, 35, 38, 39, 40, 34, 36, 34, and 30 degrees Celsius were maintained when exposed to open air. (2) It was observed that developed heat preserves boxes retained 70 % more temperature than the mixture in open air.

Additionally, it was noted that when beeswax was tested alone, it maintained a temperature of 51°C after 6 hours, while when mixed with different sensible heat storage materials, it maintained a minimum temperature of 53°C and a maximum of 68°C.

It was concluded that if sensible heat storage material is mixed with beeswax, its heat retention performance increases by 1.04 to 1.33 times. (3) Within the selected mixture, it was found that beeswax-steel bolts and beeswax-alloy steel balls and rollers have low heat retention performance. In contrast, beeswax-gritty 20 mm and beeswax-granite stone mixtures have high heat retention performance.

According to Newton's law of cooling, the cooling rate of heated material is indicated by the constant "k" value. In this test, the heat retention performance of the mixture is indicated by the "k" value, with a low value indicating a high heat retention mixture and vice versa. Accordingly, an average "k" value of 0.038954 is observed for beeswax with granite stone, indicating it to be a high heat-retaining mixture.

In contrast, an average "k" value of 0.109515 is observed for beeswax with brass, indicating it to be a low heat-retaining mixture. The "k" value for all readings is shown in ANNEXURE-1, and the average "k" value of all mixtures is shown in Table 6.

Table 6. Average "k" value of all mixture

Name of mixture	Average "k" Value
Beeswax only	0.18937
Beeswax with Steel bolts	0.093643
Beeswax with alloy Steel bolls and rollers	0.083893
Beeswax with Aluminium	0.055465
Beeswax with gritty 40 mm	0.080392
Beeswax with gritty 20 mm	0.042749
Beeswax with granite stone	0.038954
Beeswax with sand	0.085666
Beeswax with Vitrify tiles	0.07651
Beeswax with iron	0.078309
Beeswax with brass	0.109515

According to Newton's law of cooling, a program is prepared in MATLAB Software. A four-type graph is plotted: (A) actual atmospheric temperature with a cooking pot in the developed heat preserve boxes, (B) average atmospheric temperature with a cooking pot in the developed heat preserve boxes, (C) actual atmospheric temperature with a cooking pot in the open air, and (D) average atmospheric temperature with a cooking pot in the open air. This graph (See Figure 5 to Figure 8).

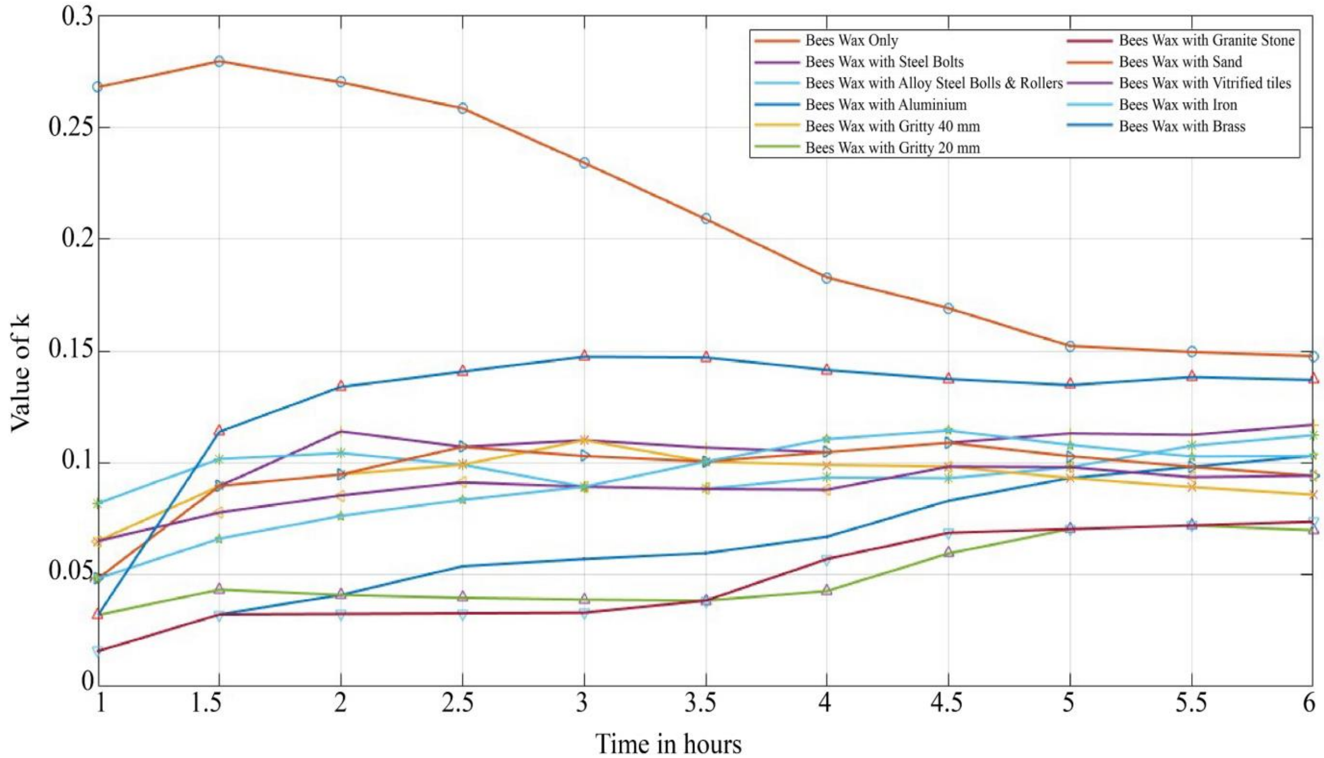

Fig. 5 (A) actual atmospheric temperature with a cooking pot in the insulated heat preserve boxes

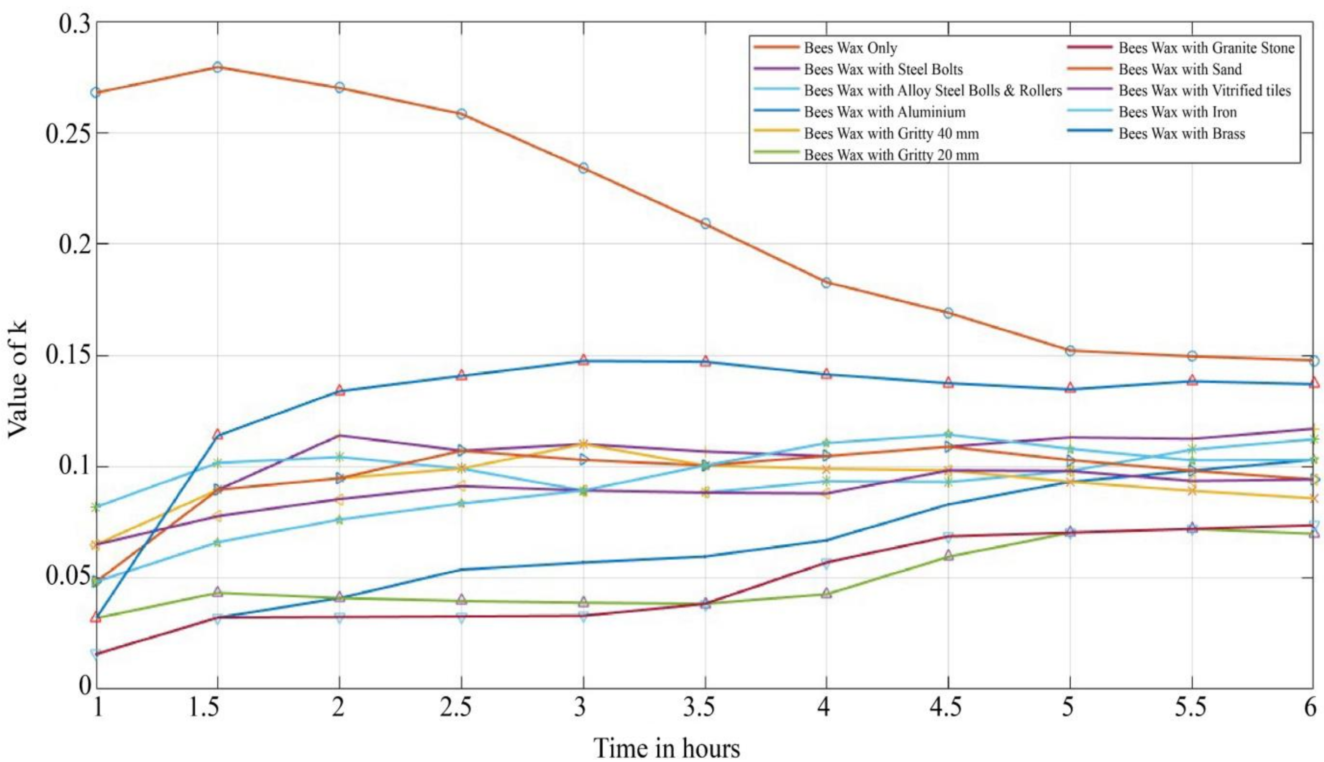

Fig. 6 (B) Average atmospheric temperature with a cooking pot in the insulated heat preserve boxes

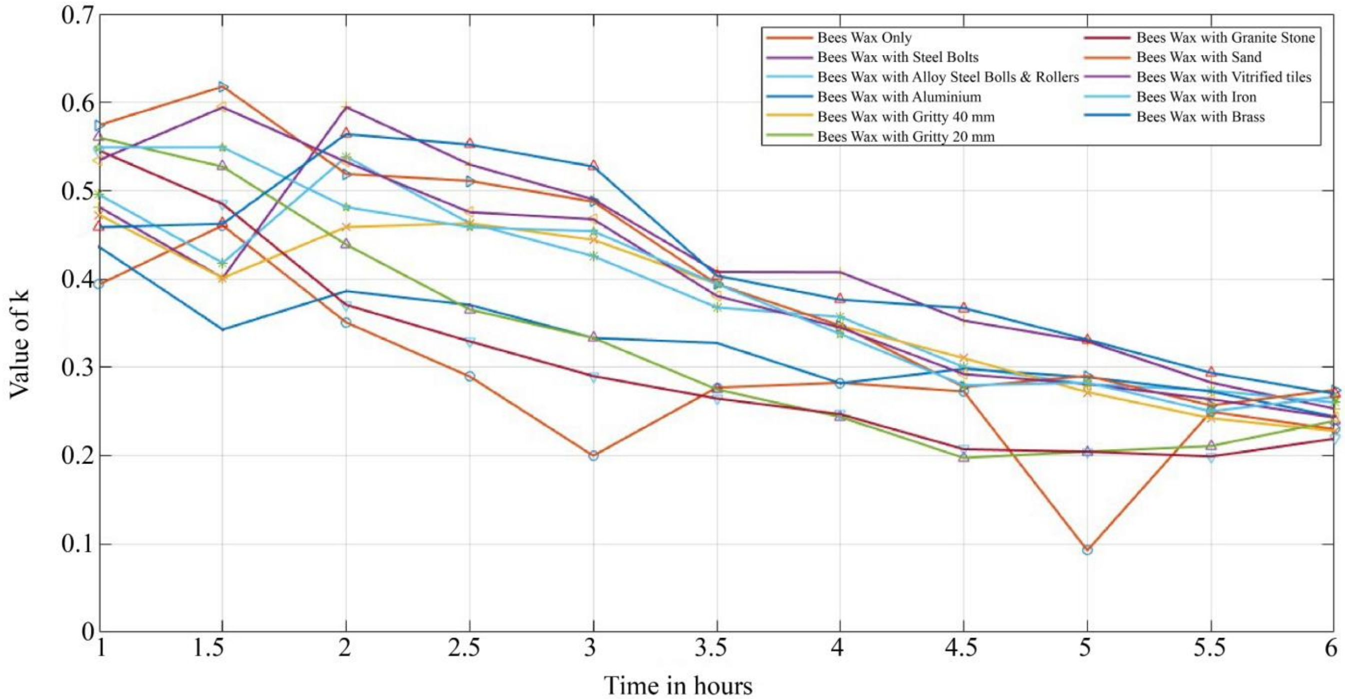

Fig. 7 (C) actual atmospheric temperature with a cooking pot in the open-air

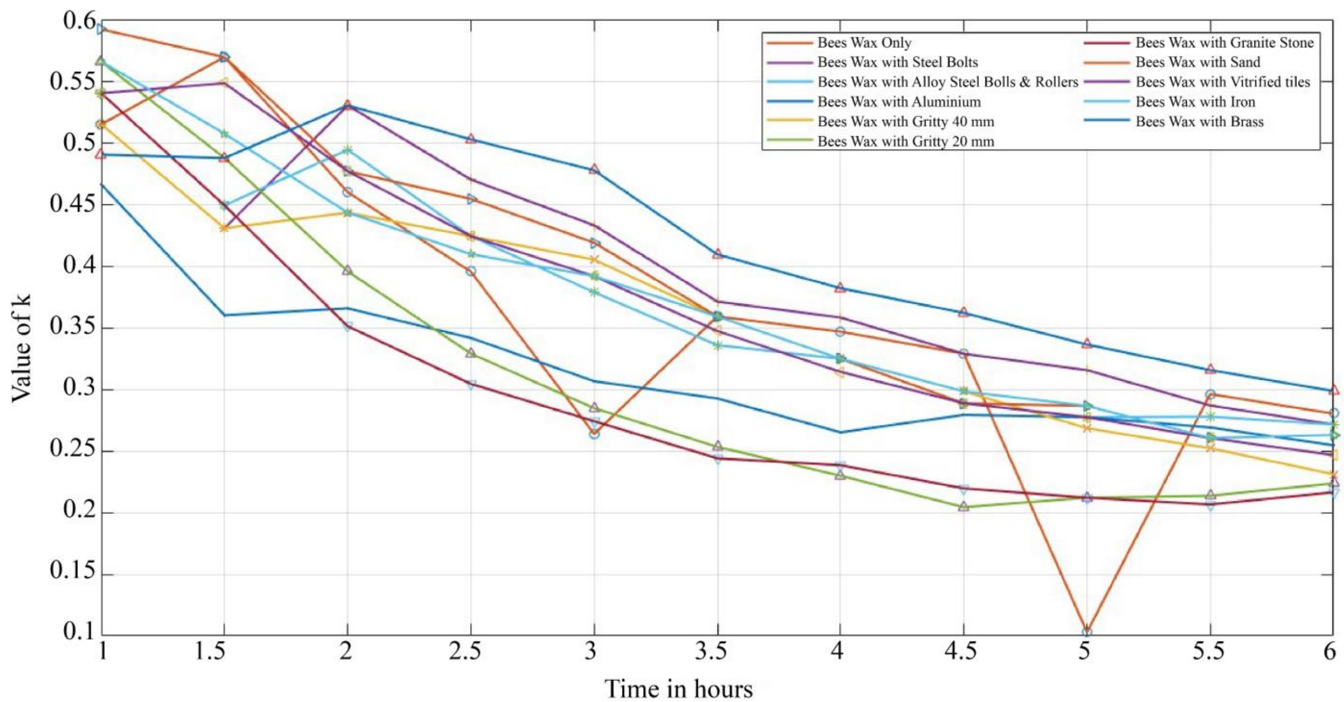

Fig. 8 (D) average atmospheric temperature with a cooking pot in the open-air

According to Graph A condition, the preserved heat (1) is best utilized within 1.5 hours when the mixture of beeswax with aluminum is employed. (2) Between 1.5 and 3.5 hours, the mixture of Bees Wax with Granite Stone is optimal. (3) Between 3.5 and 5 hours, the mixture of Bees Wax with gritty 20 mm is deemed most suitable. (3) Between 5 and 6 hours, the mixture of Bees Wax with gritty 20 mm and the mixture of Bees Wax with Granite Stone are both considered ideal.

According to the condition of graph B, if the preserved heat is to be used within 1.5 hours, the mixture of Bees Wax with Aluminium and Bees Wax with Granite Stone is considered best. If it is to be used after 1.5 to 3.5 hours, the mixture of Bees Wax with Granite Stone is considered best. For usage after 3.5 to 5 hours, the mixture of Bees Wax with gritty 20 mm is considered best. For usage after 5 to 5.5 hours, the mixture of Bees Wax with gritty 20 mm and the mixture of Bees Wax with Granite Stone is considered best, but after 5.5 to 6 hours, the mixture of Bees Wax with gritty 20 mm is considered best. According to the conditions of graph-C and D, it is found that the preserved heat can be best utilized as follows: (1) Within 1.8 hours, the mixture of Bees Wax with Aluminium is considered the best option; (2) Between 1.8 and 3.7 hours, Bees Wax alone is deemed the best choice; (3) Between 3.7 and 5 hours, the mixture of Bees Wax with gritty 20 mm is considered the most suitable; (4) Between 5 and 6 hours, the mixture of Bees Wax with Granite Stone is regarded as the best option. If graphs A and C are compared, and graphs B and D are compared, ignoring the observation of wax, it is found, as shown in Table 7 below.

According to the data in Table 3, the cooling rate of the mixture in developed heat preserve boxes is 51 to 66% lower than that in open air for up to 6 hours. Additionally, it is noted in graphs A, B, C, and D that, at the same atmospheric temperature, the value of "k" increases in developed heat preserve boxes and decreases in open air during the testing period. As observed in graphs A, B, C, and D, it is noted that despite the same ambient temperature, the value of "k" is increased in the developed heat preserve box and decreased in the open air, suggesting that the heat loss in the developed heat preserve box is reduced. The developed heat preserve box achieves a 43% improvement in heat retention compared to open air.

4.1. Research Limitations and Implications

This research has some limitations, like it is used only single family, and only one meal is cooked during one cycle of heat storage. If the heat storage material volume and size of the parabolic dish increases, so mentioned limitation is overcome.

Table 7. cooling rate in % compare to C graph or D graph

Value of "k" / hours	After 1 hour		After 3 hours		After 6 hours	
	A/B	C/D	A/B	C/D	A/B	C/D
Minimum and Maximum value of "k" when comparing the A and C graph	0.014 - 0.0719	0.4000 - 0.4827	0.0285- 0.1267	0.2263- 0.3882	0.0591- 0.1152	0.1773- 0.2380
Lover than the cooling rate in % compared to the C graph	85 - 96		67 - 87		51 - 66	
Minimum and Maximum value of "k" when comparing the B and D graph	0.014 - 0.072	0.4033- 0.5087	0.0291- 0.1277	0.2327- 0.3925	0.0606- 0.1163	0.1792- 0.2409
Lover than the cooling rate in % compared to the D graph	85 - 96		67 - 87		51 - 66	

5. Conclusion

This comprehensive study investigated the heat preservation rates of heat storage mixtures for 1 hour to 6 hours. Through rigorous experimentation and analysis, the following vital conclusions have been drawn:

1. The best heat storage mixture is gritty 20 mm, and it is found to retain the temperature up to 68 and 39 degrees Celsius after 6 hours in the developed heat preserve box and open air, respectively.
2. When beeswax was used alone, a temperature of 51°C was maintained after 6 hours, while when mixed with different sensible heat storage materials, a minimum temperature of 53°C and a maximum of 68°C were maintained. If sensible heat storage material is mixed with beeswax, its heat retention performance increases by 1.04 to 1.33 times.
3. Beeswax-steel bolts and beeswax-alloy steel balls and rollers exhibit low heat retention performance, while beeswax-gritty 20 mm and beeswax-granite stone mixtures demonstrate high heat retention performance.
4. The average cooling rate "k" of beeswax with Granite Stone is 0.038954, and with gritty 20 mm, it is 0.042749, its lowest value, indicating it is a highly performed mixture for heat retention.
5. The cooling rate of the mixture in developed heat preserve boxes is 51 to 66% lower than in the open air up to 6 hours.
6. Developed heat preserve boxes perform 43% better heat retention than open air.

In summary, valuable insights are provided by this research into the developed heat preserve box for heat retention, which is used for night cooking, and beeswax with Granite Stone mixture and beeswax with gritty 20 mm are identified as the best mixtures for heat preservation.

Nomenclature

T1 = Nearer Top Surface Temp. of the mixture of heat storage material in Box
T2 = Nearer Bottom Surface Temp. of the mixture of heat storage material in Box
T3 = Average Temp. of the mixture of heat storage material in Box
T4 = Nearer Top Surface Temp. of the mixture of heat storage material in Open Space
T5 = Nearer Bottom Surface Temp. of the mixture of heat storage material in Open Space
T6 = Average Temp. of the mixture of heat storage material in Open Space
T7 = Atmospheric Temperature
T8 = Average Atmospheric Temperature
T_t = Temperature of the body at time t
T_s = Temperature of the surrounding
k = Positive constant that depends on the area and nature of the mixture
dT = Difference of Starting and End Time
dt = Time span in hours

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Annexure-1

Material	Time, hr	Pot Temp. In Box (°C)			Pot Temp. in Open Space (°C)			Atm. Temp. (°C)	Pot Value in Box		Pot Value in Open Space	
		T1	T2	T3	T4	T5	T6	T7	k	Aver. k	k	Aver. k
Bees Wax Only	1	74	76	75	62	66	64	21	0.243902	0.18937	0.464286	0.33864
	1.5	67	69	68	50	54	52	21	0.252874		0.506667	
	2	61	65	63	48	52	50	21	0.243243		0.408163	
	2.5	58	59	59	45	50	48	21	0.231776		0.35	
	3	57	57	57	43	47	45	21	0.209524		0.322581	
	3.5	55	56	56	39	42	41	21	0.186813		0.314607	
	4	56	56	56	36	40	38	21	0.163462		0.302326	
	4.5	54	56	55	34	38	36	21	0.151025		0.285714	
	5	55	55	55	32	36	34	21	0.135922		0.273171	
	5.5	52	54	53	30	35	33	21	0.133213		0.255892	
	6	49	53	51	30	34	32	21	0.131313		0.241667	
Bees Wax with Steal Bolts	1	86	88	87	61	68	65	22	0.045113	0.093643	0.472727	0.34194
	1.5	81	83	82	56	62	59	24	0.086022		0.409241	
	2	75	78	77	43	49	46	20	0.102362		0.458333	
	2.5	73	76	75	40	46	43	20	0.103226		0.404301	
	3	70	73	72	38	42	40	20	0.104683		0.37037	
	3.5	70	70	70	37	42	40	21	0.096852		0.324675	
	4	67	69	68	35	39	37	20	0.09322		0.304598	
	4.5	64	66	65	34	38	36	20	0.096618		0.27907	
	5	60	63	62	31	36	34	20	0.1		0.266667	

	5.5	58	62	60	31	36	34	20	0.099174		0.242424	
	6	56	58	57	30	35	33	20	0.102804		0.228916	
Bees Wax with Alloy Steal Bolls & Rollers	1	84	86	85	61	65	63	18	0.071942	0.083893	0.461538	0.30554
	1.5	80	82	81	56	60	58	18	0.088889		0.380952	
	2	77	79	78	45	50	48	18	0.090909		0.411765	
	2.5	75	77	76	43	48	46	18	0.086154		0.352	
	3	74	76	75	42	46	44	17	0.076336		0.306667	
	3.5	71	75	73	40	45	43	18	0.07649		0.276878	
	4	68	72	70	38	42	40	17	0.079365		0.260417	
	4.5	66	70	68	37	42	40	18	0.080146		0.236407	
	5	63	67	65	35	40	38	18	0.084034		0.226087	
	5.5	59	63	61	33	37	35	19	0.093323		0.229885	
	6	56	60	58	30	35	33	18	0.095238		0.218391	
Bees Wax with Aluminum	1	88	89	89	64	68	66	18	0.013986	0.055465	0.4	0.26432
	1.5	86	88	87	60	65	63	18	0.028369		0.307692	
	2	84	86	85	55	59	57	18	0.035971		0.309091	
	2.5	80	84	82	50	54	52	18	0.047059		0.286792	
	3	78	81	80	47	52	50	18	0.049751		0.25641	
	3.5	76	79	78	45	49	47	18	0.051948		0.243281	
	4	74	76	75	44	48	46	18	0.05814		0.22	
	4.5	69	71	70	39	43	41	18	0.071685		0.22924	
	5	64	68	66	36	40	38	18	0.08		0.226087	
	5.5	61	65	63	34	38	36	18	0.083916		0.218182	
	6	59	61	60	33	37	35	19	0.089286		0.210728	
Bees Wax with Big Size Stone	1	84	88	86	63	65	64	19	0.057971	0.080392	0.448276	0.29680
	1.5	80	84	82	57	61	59	18	0.078431		0.365782	
	2	77	80	79	48	53	51	18	0.082707		0.371429	
	2.5	74	78	76	44	48	46	18	0.086154		0.352	
	3	70	74	72	40	44	42	18	0.095238		0.333333	
	3.5	70	72	71	39	42	41	17	0.085489		0.28866	
	4	68	70	69	38	42	40	17	0.084		0.260417	
	4.5	65	68	67	36	41	39	18	0.084481		0.243728	
	5	64	67	66	36	41	39	18	0.08		0.219355	
	5.5	63	66	65	35	41	38	18	0.076394		0.193424	
	6	62	65	64	34	41	38	18	0.073446		0.188406	
Bees Wax with Small Size Stone	1	86	89	88	61	63	62	17	0.027778	0.042749	0.474576	0.25514
	1.5	85	87	86	54	58	56	17	0.037559		0.404762	
	2	84	86	85	52	56	54	17	0.035461		0.327273	
	2.5	82	86	84	50	55	53	17	0.034286		0.27156	
	3	81	85	83	50	54	52	17	0.038647		0.260317	
	3.5	80	83	82	49	52	51	17	0.028777		0.193971	
	4	78	81	80	48	52	50	17	0.036765		0.182243	

	4.5	73	76	75	47	52	50	17	0.050891		0.167715	
	5	70	72	71	44	48	46	17	0.059843		0.172549	
	5.5	68	70	69	40	45	43	17	0.061091		0.172635	
	6	66	69	68	36	41	39	17	0.05914		0.178947	
Bees Wax with Granite Stone	1	88	89	89	61	65	63	18	0.0000	0.038954	0.461538	0.24339
	1.5	86	88	87	56	60	58	17	0.018519		0.374269	
	2	84	88	86	55	59	57	17	0.028169		0.292035	
	2.5	83	86	85	52	57	55	17	0.028369		0.252252	
	3	82	86	84	50	56	53	17	0.028571		0.21021	
	3.5	80	83	82	48	55	52	17	0.033126		0.201058	
	4	76	78	77	46	51	49	17	0.048872		0.195238	
	4.5	71	75	73	46	50	48	17	0.05857		0.173545	
	5	70	72	71	44	48	46	17	0.059843		0.172549	
	5.5	68	70	69	42	46	44	17	0.061091		0.167273	
	6	66	68	67	38	42	40	18	0.063361		0.177305	
Bee Wax with Sand	1	85	88	87	59	63	61	20	0.058824	0.085666	0.522523	0.33270
	1.5	80	84	82	50	54	52	19	0.079602		0.487179	
	2	78	80	79	46	51	49	19	0.083969		0.405941	
	2.5	74	76	75	42	46	44	20	0.096		0.391489	
	3	71	74	73	38	43	41	19	0.090667		0.351254	
	3.5	68	73	71	38	43	41	20	0.089728		0.307692	
	4	66	70	68	37	42	40	19	0.091667		0.28022	
	4.5	63	67	65	37	42	40	19	0.094967		0.241546	
	5	62	65	64	35	39	37	19	0.089655		0.238202	
	5.5	61	64	63	34	39	37	19	0.085375		0.216547	
	6	61	63	62	31	36	34	19	0.081871		0.217054	
BeeWax with vitrified tiles	1	84	88	86	58	62	60	19	0.057971	0.07651	0.535714	0.31843
	1.5	80	85	83	51	55	53	19	0.069136		0.469841	
	2	78	81	80	46	51	49	18	0.074627		0.398058	
	2.5	76	78	77	40	51	46	18	0.079389		0.352	
	3	73	76	75	40	46	43	18	0.077519		0.333333	
	3.5	70	74	72	40	44	42	18	0.07649		0.276878	
	4	68	73	71	39	42	41	18	0.076		0.257895	
	4.5	65	69	67	38	41	40	18	0.084481		0.236407	
	5	63	66	65	35	40	38	18	0.084034		0.226087	
	5.5	62	65	64	34	39	37	19	0.081505		0.216547	
	6	60	63	62	34	38	36	18	0.08046		0.2	
Bees Wax with Iron	1	86	88	87	60	64	62	18	0.042553	0.078309	0.482759	0.31131
	1.5	82	86	84	52	57	55	18	0.057971		0.444444	
	2	79	83	81	48	53	51	18	0.066667		0.371429	
	2.5	76	80	78	46	48	47	18	0.072727		0.340594	

	3	74	76	75	40	46	43	18	0.077519		0.323024	
	3.5	68	73	71	39	42	41	18	0.086857		0.294737	
	4	64	70	67	38	41	40	18	0.095041		0.274194	
	4.5	61	67	64	38	40	39	18	0.097928		0.236407	
	5	60	66	63	35	39	37	18	0.092308		0.232967	
	5.5	60	64	62	35	39	37	18	0.087774		0.211788	
	6	59	60	60	31	36	34	18	0.084058		0.212121	
	1	86	89	88	61	68	65	19	0.028571		0.42735	
	1.5	78	82	80	52	60	56	18	0.099502		0.412121	
	2	73	77	75	41	51	46	18	0.116279		0.44	
	2.5	70	72	71	37	45	41	18	0.1216		0.412632	
	3	64	70	67	35	39	37	18	0.126722		0.388278	
Bees Wax with Brass	3.5	61	66	64	35	38	37	18	0.125908	0.109515	0.322981	0.34197
	4	60	63	62	32	37	35	19	0.122807		0.306818	
	4.5	58	61	60	30	35	33	18	0.116959		0.291188	
	5	56	60	58	30	34	32	18	0.114286		0.269767	
	5.5	53	57	55	29	32	31	18	0.116764		0.252406	
	6	50	55	53	29	31	30	18	0.115265		0.238095	

Annexure-2

(A)

Program for an actual atmospheric temperature with a cooking pot in the developed heat preserve boxes.

```
% Ts= Starting Temperature of Mixture
% Te= End Temperature of the mixture at a time
% dt= Time Scale
% T1= Atmospheric Temperature at time
% K= constant of Newton's law of cooling
% 1= Value of Beeswax
% 2= Value of Beeswax with Steal Bolts mixture
% 3= Value of Beeswax with Alloy Steel Bolls & Rollers mixture
% 4= Value of Beeswax with Aluminium mixture
% 5= Value of Beeswax with Gritty 40 mm mixture
% 6= Value of Beeswax with Gritty 20 mm mixture
% 7= Value of Beeswax with Granite Stone mixture
% 8= Value of Beeswax with with Sand mixture
% 9= Value of Beeswax with Vitrified tiles mixture
% 10= Value of Beeswax with Iron mixture
% 11= Value of Beeswax with Brass mixture

Ts1=[90 90 90 90 90 90 90 90 90 90 90];
Te1=[75 68 63 59 57 56 56 55 55 53 51];
dt1=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T11=[21 21 21 21 21 21 21 21 21 21 21];

K1=(Ts1-Te1)./(dt1.*(((Ts1+Te1)./2)-T11))
plot(dt1,K1,"o",'HandleVisibility','off')
hold on;
xlabel('Time in hours');
```

```
ylabel('Value of k');
grid on;
plot(dt1,K1,"-",'DisplayName','Bees Wax Only','LineWidth',1.5)
%legend('Beeswax')

Ts2=[90 90 90 90 90 90 90 90 90 90 90];
Te2=[87 82 77 75 72 70 68 65 62 60 57];
dt2=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T12=[22 24 20 20 20 21 20 20 20 20 20];

K2=(Ts2-Te2)./(dt2.*(((Ts2+Te2)./2)-T12))
plot(dt2,K2,"+",'HandleVisibility','off')
plot(dt2,K2,"-",'DisplayName','Bees Wax with Steel Bolts','LineWidth',1.5)

Ts3=[90 90 90 90 90 90 90 90 90 90 90];
Te3=[85 81 78 76 75 73 70 68 65 61 58];
dt3=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T13=[18 18 18 18 17 18 17 18 18 19 18];

K3=(Ts3-Te3)./(dt3.*(((Ts3+Te3)./2)-T13))
plot(dt3,K3,"*",'HandleVisibility','off')
plot(dt3,K3,"-",'DisplayName','Bees Wax with Alloy Steel Bolls & Rollers','LineWidth',1.5)

Ts4=[90 90 90 90 90 90 90 90 90 90 90];
Te4=[89 87 85 82 80 78 75 70 66 63 60];
dt4=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T14=[18 18 18 18 18 18 18 18 18 18 19];

K4=(Ts4-Te4)./(dt4.*(((Ts4+Te4)./2)-T14))
plot(dt4,K4,".",'HandleVisibility','off')
plot(dt4,K4,"-",'DisplayName','Bees Wax with Aluminium','LineWidth',1.5)

Ts5=[90 90 90 90 90 90 90 90 90 90 90];
Te5=[86 82 79 76 72 71 69 67 66 65 64];
dt5=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T15=[19 18 18 18 18 17 17 18 18 18 18];

K5=(Ts5-Te5)./(dt5.*(((Ts5+Te5)./2)-T15))
plot(dt5,K5,"x",'HandleVisibility','off')
plot(dt5,K5,"-",'DisplayName','Bees Wax with Gritty 40 mm','LineWidth',1.5)

Ts6=[90 90 90 90 90 90 90 90 90 90 90];
Te6=[88 86 85 84 83 82 80 75 71 69 68];
dt6=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T16=[17 17 17 17 17 17 17 17 17 17 17];

K6=(Ts6-Te6)./(dt6.*(((Ts6+Te6)./2)-T16))
plot(dt6,K6,"^",'HandleVisibility','off')
plot(dt6,K6,"-",'DisplayName','Bees Wax with Gritty 20 mm','LineWidth',1.5)

Ts7=[90 90 90 90 90 90 90 90 90 90 90];
Te7=[89 87 86 85 84 82 77 73 71 69 67];
dt7=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T17=[18 17 17 17 17 17 17 17 17 17 18];
```

```
K7=(Ts7-Te7)./(dt7.*(((Ts7+Te7)./2)-T17))
plot(dt7,K7,"v",'HandleVisibility','off')
plot(dt7,K7,"-",'DisplayName','Bees Wax with Granite Stone','LineWidth',1.5)

Ts8=[90 90 90 90 90 90 90 90 90 90 90];
Te8=[87 82 79 75 73 71 68 65 64 63 62];
dt8=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T18=[20 19 19 20 19 20 19 19 19 19 19];

K8=(Ts8-Te8)./(dt8.*(((Ts8+Te8)./2)-T18))
plot(dt8,K8,">",'HandleVisibility','off')
plot(dt8,K8,"-",'DisplayName','Bees Wax with Sand','LineWidth',1.5)

Ts9=[90 90 90 90 90 90 90 90 90 90 90];
Te9=[86 83 80 77 75 73 71 67 65 64 62];
dt9=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T19=[19 19 18 18 18 18 18 18 18 19 18];

K9=(Ts9-Te9)./(dt9.*(((Ts9+Te9)./2)-T19))
plot(dt9,K9,"<",'HandleVisibility','off')
plot(dt9,K9,"-",'DisplayName','Bees Wax with Vitrified tiles','LineWidth',1.5)

Ts10=[90 90 90 90 90 90 90 90 90 90 90];
Te10=[87 84 81 78 75 71 67 64 63 62 60];
dt10=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T110=[18 18 18 18 18 18 18 18 18 18 18];

K10=(Ts10-Te10)./(dt10.*(((Ts10+Te10)./2)-T110))
plot(dt10,K10,"pentagram",'HandleVisibility','off')
plot(dt10,K10,"-",'DisplayName','Bees Wax with Iron','LineWidth',1.5)

Ts11=[90 90 90 90 90 90 90 90 90 90 90];
Te11=[88 80 75 71 67 64 62 60 58 55 53];
dt11=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T111=[19 18 18 18 18 18 19 18 18 18 18];

K11=(Ts11-Te11)./(dt11.*(((Ts11+Te11)./2)-T111))
plot(dt11,K11,'^r','HandleVisibility','off')
plot(dt11,K11,"-",'DisplayName','Bees Wax with Brass','LineWidth',1.5)
hold off;

lgd=legend;
lgd.NumColumns=2;
```

(B)

Program for an average atmospheric temperature with cooking pot in the developed heat preserve boxes

```
% Ts= Starting Temperature of Mixture
% Te= End Temperature of mixture at time
% dt= Time Scale
% T1= Atmospheric Temperature at time
% K= constant of Newton's law of cooling
% 1= Value of Beeswax
% 2= Value of Beeswax with Steal Bolts mixture
% 3= Value of Beeswax with Alloy Steal Bolls & Rollers mixture
% 4= Value of Beeswax with Aluminium mixture
% 5= Value of Beeswax with Gritty 40 mm mixture
% 6= Value of Beeswax with Gritty 20 mm mixture
```

```
% 7= Value of Beeswax with Granite Stone mixture
% 8= Value of Beeswax with with Sand mixture
% 9= Value of Beeswax with Vitrified tiles mixture
% 10= Value of Beeswax with Iron mixture
% 11= Value of Beeswax with Brass mixture

Ts1=[90 90 90 90 90 90 90 90 90 90 90];
Te1=[75 68 63 59 57 56 56 55 55 53 51];
dt1=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T11=[18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5];

K1=(Ts1-Te1)./(dt1.*(((Ts1+Te1)./2)-T11))
plot(dt1,K1,"o",'HandleVisibility','off')
hold on;
xlabel('Time in hours');
ylabel('Value of k');
grid on;
plot(dt1,K1,"-",'DisplayName','Bees Wax Only','LineWidth',1.5)
%legend('Beeswax')

Ts2=[90 90 90 90 90 90 90 90 90 90 90];
Te2=[87 82 77 75 72 70 68 65 62 60 57];
dt2=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T12=[18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5];

K2=(Ts2-Te2)./(dt2.*(((Ts2+Te2)./2)-T12))
plot(dt2,K2,"+",'HandleVisibility','off')
plot(dt2,K2,"-",'DisplayName','Bees Wax with Steel Bolts','LineWidth',1.5)

Ts3=[90 90 90 90 90 90 90 90 90 90 90];
Te3=[85 81 78 76 75 73 70 68 65 61 58];
dt3=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T13=[18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5];

K3=(Ts3-Te3)./(dt3.*(((Ts3+Te3)./2)-T13))
plot(dt3,K3,"*",'HandleVisibility','off')
plot(dt3,K3,"-",'DisplayName','Bees Wax with Alloy Steel Bolls & Rollers','LineWidth',1.5)

Ts4=[90 90 90 90 90 90 90 90 90 90 90];
Te4=[89 87 85 82 80 78 75 70 66 63 60];
dt4=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T14=[18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5];

K4=(Ts4-Te4)./(dt4.*(((Ts4+Te4)./2)-T14))
plot(dt4,K4,".",'HandleVisibility','off')
plot(dt4,K4,"-",'DisplayName','Bees Wax with Aluminium','LineWidth',1.5)

Ts5=[90 90 90 90 90 90 90 90 90 90 90];
Te5=[86 82 79 76 72 71 69 67 66 65 64];
dt5=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T15=[18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5];

K5=(Ts5-Te5)./(dt5.*(((Ts5+Te5)./2)-T15))
plot(dt5,K5,"x",'HandleVisibility','off')
plot(dt5,K5,"-",'DisplayName','Bees Wax with Gritty 40 mm','LineWidth',1.5)
```

```
Ts6=[90 90 90 90 90 90 90 90 90 90 90];
Te6=[88 86 85 84 83 82 80 75 71 69 68];
dt6=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T16=[18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5];

K6=(Ts6-Te6)./(dt6.*(((Ts6+Te6)./2)-T16))
plot(dt6,K6,"^",'HandleVisibility','off')
plot(dt6,K6,"-",'DisplayName','Bees Wax with Gritty 20 mm','LineWidth',1.5)

Ts7=[90 90 90 90 90 90 90 90 90 90 90];
Te7=[89 87 86 85 84 82 77 73 71 69 67];
dt7=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T17=[18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5];

K7=(Ts7-Te7)./(dt7.*(((Ts7+Te7)./2)-T17))
plot(dt7,K7,"v",'HandleVisibility','off')
plot(dt7,K7,"-",'DisplayName','Bees Wax with Granite Stone','LineWidth',1.5)

Ts8=[90 90 90 90 90 90 90 90 90 90 90];
Te8=[87 82 79 75 73 71 68 65 64 63 62];
dt8=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T18=[18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5];

K8=(Ts8-Te8)./(dt8.*(((Ts8+Te8)./2)-T18))
plot(dt8,K8,">",'HandleVisibility','off')
plot(dt8,K8,"-",'DisplayName','Bees Wax with Sand','LineWidth',1.5)

Ts9=[90 90 90 90 90 90 90 90 90 90 90];
Te9=[86 83 80 77 75 73 71 67 65 64 62];
dt9=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T19=[18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5];

K9=(Ts9-Te9)./(dt9.*(((Ts9+Te9)./2)-T19))
plot(dt9,K9,"<",'HandleVisibility','off')
plot(dt9,K9,"-",'DisplayName','Bees Wax with Vitrified tiles','LineWidth',1.5)

Ts10=[90 90 90 90 90 90 90 90 90 90 90];
Te10=[87 84 81 78 75 71 67 64 63 62 60];
dt10=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T110=[18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5];

K10=(Ts10-Te10)./(dt10.*(((Ts10+Te10)./2)-T110))
plot(dt10,K10,"pentagram",'HandleVisibility','off')
plot(dt10,K10,"-",'DisplayName','Bees Wax with Iron','LineWidth',1.5)

Ts11=[90 90 90 90 90 90 90 90 90 90 90];
Te11=[88 80 75 71 67 64 62 60 58 55 53];
dt11=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T111=[18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5];

K11=(Ts11-Te11)./(dt11.*(((Ts11+Te11)./2)-T111))
plot(dt11,K11,'^r','HandleVisibility','off')
plot(dt11,K11,"-",'DisplayName','Bees Wax with Brass','LineWidth',1.5)
hold off;

lgd=legend;
lgd.NumColumns=2;
```

(C)

Program for an actual atmospheric temperature with cooking pot in the open-air

```
% Ts= Starting Temperature of Mixture
% Te= End Temperature of mixture at time
% dt= Time Scale
% T1= Atmospheric Temperature at time
% K= constant of Newton's law of cooling
% 1= Value of Beeswax
% 2= Value of Beeswax with Steal Bolts mixture
% 3= Value of Beeswax with Alloy Steel Bolls & Rollers mixture
% 4= Value of Beeswax with Aluminium mixture
% 5= Value of Beeswax with Gritty 40 mm mixture
% 6= Value of Beeswax with Gritty 20 mm mixture
% 7= Value of Beeswax with Granite Stone mixture
% 8= Value of Beeswax with with Sand mixture
% 9= Value of Beeswax with Vitrified tiles mixture
% 10= Value of Beeswax with Iron mixture
% 11= Value of Beeswax with Brass mixture

Ts1=[90 90 90 90 90 90 90 90 90 90 90];
Te1=[64 52 50 48 54 41 38 36 64 33 32];
dt1=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T11=[21 21 21 21 21 21 21 21 21 21 21];

K1=(Ts1-Te1)./(dt1.*(((Ts1+Te1)./2)-T11))
plot(dt1,K1,"o",'HandleVisibility','off')
hold on;
xlabel('Time in hours');
ylabel('Value of k');
grid on;
plot(dt1,K1,"-",'DisplayName','Bees Wax Only','LineWidth',1.5)
%legend('Beeswax')

Ts2=[90 90 90 90 90 90 90 90 90 90 90];
Te2=[64 59 46 43 40 40 37 36 34 34 33];
dt2=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T12=[22 24 20 20 20 21 20 20 20 20 20];

K2=(Ts2-Te2)./(dt2.*(((Ts2+Te2)./2)-T12))
plot(dt2,K2,"+",'HandleVisibility','off')
plot(dt2,K2,"-",'DisplayName','Bees Wax with Steel Bolts','LineWidth',1.5)

Ts3=[90 90 90 90 90 90 90 90 90 90 90];
Te3=[63 58 48 46 44 43 40 40 38 35 33];
dt3=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T13=[18 18 18 18 17 18 17 18 18 19 18];

K3=(Ts3-Te3)./(dt3.*(((Ts3+Te3)./2)-T13))
plot(dt3,K3,"*",'HandleVisibility','off')
plot(dt3,K3,"-",'DisplayName','Bees Wax with Alloy Steel Bolls & Rollers','LineWidth',1.5)

Ts4=[90 90 90 90 90 90 90 90 90 90 90];
Te4=[66 63 56 52 50 47 46 41 38 36 35];
dt4=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T14=[18 18 18 18 18 18 18 18 18 18 19];
```

```
K4=(Ts4-Te4)./(dt4.*(((Ts4+Te4)./2)-T14))
plot(dt4,K4,".",'HandleVisibility','off')
plot(dt4,K4,"-",'DisplayName','Bees Wax with Aluminium','LineWidth',1.5)

Ts5=[90 90 90 90 90 90 90 90 90 90 90];
Te5=[64 59 51 46 42 41 40 39 39 38 38];
dt5=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T15=[19 18 18 18 18 17 17 18 18 18 18];

K5=(Ts5-Te5)./(dt5.*(((Ts5+Te5)./2)-T15))
plot(dt5,K5,"x",'HandleVisibility','off')
plot(dt5,K5,"-",'DisplayName','Bees Wax with Gritty 40 mm','LineWidth',1.5)

Ts6=[90 90 90 90 90 90 90 90 90 90 90];
Te6=[62 56 54 53 52 51 50 50 46 43 39];
dt6=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T16=[17 17 17 17 17 17 17 17 17 17 17];

K6=(Ts6-Te6)./(dt6.*(((Ts6+Te6)./2)-T16))
plot(dt6,K6,"^",'HandleVisibility','off')
plot(dt6,K6,"-",'DisplayName','Bees Wax with Gritty 20 mm','LineWidth',1.5)

Ts7=[90 90 90 90 90 90 90 90 90 90 90];
Te7=[63 58 57 55 53 52 49 48 46 44 40];
dt7=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T17=[18 17 17 17 17 17 17 17 17 17 18];

K7=(Ts7-Te7)./(dt7.*(((Ts7+Te7)./2)-T17))
plot(dt7,K7,"v",'HandleVisibility','off')
plot(dt7,K7,"-",'DisplayName','Bees Wax with Granite Stone','LineWidth',1.5)

Ts8=[90 90 90 90 90 90 90 90 90 90 90];
Te8=[61 52 49 44 41 41 40 40 37 37 34];
dt8=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T18=[20 19 19 20 19 20 19 19 19 19 19];

K8=(Ts8-Te8)./(dt8.*(((Ts8+Te8)./2)-T18))
plot(dt8,K8,">",'HandleVisibility','off')
plot(dt8,K8,"-",'DisplayName','Bees Wax with Sand','LineWidth',1.5)

Ts9=[90 90 90 90 90 90 90 90 90 90 90];
Te9=[63 53 49 46 43 42 41 40 38 37 36];
dt9=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T19=[19 19 18 18 18 18 18 18 18 19 18];

K9=(Ts9-Te9)./(dt9.*(((Ts9+Te9)./2)-T19))
plot(dt9,K9,"<",'HandleVisibility','off')
plot(dt9,K9,"-",'DisplayName','Bees Wax with Vitrified tiles','LineWidth',1.5)

Ts10=[90 90 90 90 90 90 90 90 90 90 90];
Te10=[62 55 51 47 43 41 40 39 37 37 34];
dt10=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T110=[18 18 18 18 18 18 18 18 18 18 18];

K10=(Ts10-Te10)./(dt10.*(((Ts10+Te10)./2)-T110))
plot(dt10,K10,"pentagram",'HandleVisibility','off')
plot(dt10,K10,"-",'DisplayName','Bees Wax with Iron','LineWidth',1.5)
```

```
Ts11=[90 90 90 90 90 90 90 90 90 90 90];
Te11=[65 56 46 41 37 37 35 33 32 31 30];
dt11=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T111=[19 18 18 18 18 18 19 18 18 18 18];

K11=(Ts11-Te11)./(dt11.*(((Ts11+Te11)./2)-T111))
plot(dt11,K11,'^r','HandleVisibility','off')
plot(dt11,K11,"-",'DisplayName','Bees Wax with Brass','LineWidth',1.5)
hold off;

lgd=legend;
lgd.NumColumns=2;
```

(D)

Program for an average atmospheric temperature with cooking pot in the open-air

```
% Ts= Starting Temperature of Mixture
% Te= End Temperature of mixture at time
% dt= Time Scale
% T1= Atmospheric Temperature at time
% K= constant of Newton's law of cooling
% 1= Value of Beeswax
% 2= Value of Beeswax with Steel Bolts mixture
% 3= Value of Beeswax with Alloy Steel Bolls & Rollers mixture
% 4= Value of Beeswax with Aluminium mixture
% 5= Value of Beeswax with Gritty 40 mm mixture
% 6= Value of Beeswax with Gritty 20 mm mixture
% 7= Value of Beeswax with Granite Stone mixture
% 8= Value of Beeswax with with Sand mixture
% 9= Value of Beeswax with Vitrified tiles mixture
% 10= Value of Beeswax with Iron mixture
% 11= Value of Beeswax with Brass mixture

Ts1=[90 90 90 90 90 90 90 90 90 90 90];
Te1=[64 52 50 48 54 41 38 36 64 33 32];
dt1=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T11=[26.5 26.5 26.5 26.5 26.5 26.5 26.5 26.5 26.5 26.5 26.5];

K1=(Ts1-Te1)./(dt1.*(((Ts1+Te1)./2)-T11))
plot(dt1,K1,"o",'HandleVisibility','off')
hold on;
xlabel('Time in hours');
ylabel('Value of k');
grid on;
plot(dt1,K1,"-",'DisplayName','Bees Wax Only','LineWidth',1.5)
%legend('Beeswax')

Ts2=[90 90 90 90 90 90 90 90 90 90 90];
Te2=[64 59 46 43 40 40 37 36 34 34 33];
dt2=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T12=[18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5];

K2=(Ts2-Te2)./(dt2.*(((Ts2+Te2)./2)-T12))
plot(dt2,K2,"+",'HandleVisibility','off')
plot(dt2,K2,"-",'DisplayName','Bees Wax with Steel Bolts','LineWidth',1.5)
```

```
Ts3=[90 90 90 90 90 90 90 90 90 90 90];
Te3=[63 58 48 46 44 43 40 40 38 35 33];
dt3=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T13=[18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5];

K3=(Ts3-Te3)./(dt3.*(((Ts3+Te3)./2)-T13))
plot(dt3,K3,"*",'HandleVisibility','off')
plot(dt3,K3,"-",'DisplayName','Bees Wax with Alloy Steel Bolls & Rollers','LineWidth',1.5)

Ts4=[90 90 90 90 90 90 90 90 90 90 90];
Te4=[66 63 56 52 50 47 46 41 38 36 35];
dt4=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T14=[18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5];

K4=(Ts4-Te4)./(dt4.*(((Ts4+Te4)./2)-T14))
plot(dt4,K4,".",'HandleVisibility','off')
plot(dt4,K4,"-",'DisplayName','Bees Wax with Aluminium','LineWidth',1.5)

Ts5=[90 90 90 90 90 90 90 90 90 90 90];
Te5=[64 59 51 46 42 41 40 39 39 38 38];
dt5=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T15=[18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5];

K5=(Ts5-Te5)./(dt5.*(((Ts5+Te5)./2)-T15))
plot(dt5,K5,"x",'HandleVisibility','off')
plot(dt5,K5,"-",'DisplayName','Bees Wax with Gritty 40 mm','LineWidth',1.5)

Ts6=[90 90 90 90 90 90 90 90 90 90 90];
Te6=[62 56 54 53 52 51 50 50 46 43 39];
dt6=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T16=[18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5];

K6=(Ts6-Te6)./(dt6.*(((Ts6+Te6)./2)-T16))
plot(dt6,K6,"^",'HandleVisibility','off')
plot(dt6,K6,"-",'DisplayName','Bees Wax with Gritty 20 mm','LineWidth',1.5)

Ts7=[90 90 90 90 90 90 90 90 90 90 90];
Te7=[63 58 57 55 53 52 49 48 46 44 40];
dt7=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T17=[18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5];

K7=(Ts7-Te7)./(dt7.*(((Ts7+Te7)./2)-T17))
plot(dt7,K7,"v",'HandleVisibility','off')
plot(dt7,K7,"-",'DisplayName','Bees Wax with Granite Stone','LineWidth',1.5)

Ts8=[90 90 90 90 90 90 90 90 90 90 90];
Te8=[61 52 49 44 41 41 40 40 37 37 34];
dt8=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T18=[18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5];

K8=(Ts8-Te8)./(dt8.*(((Ts8+Te8)./2)-T18))
plot(dt8,K8,">",'HandleVisibility','off')
plot(dt8,K8,"-",'DisplayName','Bees Wax with Sand','LineWidth',1.5)
```

```
Ts9=[90 90 90 90 90 90 90 90 90 90 90];
Te9=[63 53 49 46 43 42 41 40 38 37 36];
dt9=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T19=[18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5];

K9=(Ts9-Te9)./(dt9.*(((Ts9+Te9)./2)-T19))
plot(dt9,K9,"<",'HandleVisibility','off')
plot(dt9,K9,"-",'DisplayName','Bees Wax with Vitrified tiles','LineWidth',1.5)

Ts10=[90 90 90 90 90 90 90 90 90 90 90];
Te10=[62 55 51 47 43 41 40 39 37 37 34];
dt10=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T110=[18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5];

K10=(Ts10-Te10)./(dt10.*(((Ts10+Te10)./2)-T110))
plot(dt10,K10,"pentagram",'HandleVisibility','off')
plot(dt10,K10,"-",'DisplayName','Bees Wax with Iron','LineWidth',1.5)

Ts11=[90 90 90 90 90 90 90 90 90 90 90];
Te11=[65 56 46 41 37 37 35 33 32 31 30];
dt11=[1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6];
T111=[18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5 18.5];

K11=(Ts11-Te11)./(dt11.*(((Ts11+Te11)./2)-T111))
plot(dt11,K11,'^r','HandleVisibility','off')
plot(dt11,K11,"-",'DisplayName','Bees Wax with Brass','LineWidth',1.5)
hold off;

lgd=legend;
lgd.NumColumns=2;
```