Assessment of Cereal-Grain Warming Pad as a Heat Source for Newborn Transport

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Objective: *The study assessed warming pad (WP) filled with either mung beans or dry corn used in feeding livestocks as a heat source for newborn transport. Its use was to compensate for lack of transport incubator or to employ as a supplemental heat source for warming the infant or incubator when transport made in cold weather.*

Material and Method: *The WP was made of a strong-cotton-cloth bag (the fabric for making jeans) with a size of A4 paper sheet. The bag was filled with one kilogram of either mung beans or dry corn (used in feeding livestocks). The WP was heated in a 800-watts microwave oven for 2 minutes with grains thoroughly mixed inside to distribute heat evenly and put in a disposable A4-size brown envelope. The temperature at the surface of the brown envelope with the WP inside was recorded every 5 minutes for 120 minutes to assess which cereal grain could emit more heat and keep the heat longer. Then the WP was heated in the microwave oven for 1, $1^1/_2$ and 2 minutes, placed in the same size of brown envelope and covered with two towels. The temperatures at the surface of the brown envelope and each layer of towels were recorded with the same frequency and duration.*

Results: *The cereal-grain WPs, both mung beans and dry corn, were equally effective in producing heat when warmed in the microwave oven. The mean maximal temperatures at the surface of brown envelope were too high for direct application to newborns. The mean maximal temperatures of towels covering the paper envelope with WP heated in the microwave oven for 1 minute were as followed. At the first towel, which was close to the WP, the mean temperature reached 42^0 C (107.6^0 F) in 10 minutes after warming and was maintained $\geq$ 42^0 C for 10 minutes. All temperature measurements at the first towel was $\leq 42^0$ C at 35 minutes. At 2 hours the mean temperature of the first towel was 35.6^0 C (96.1^0 F) which was higher than room temperature by 5.3^0 C (41.5^0 F). The maximal mean temperature measured at the second towel, representing the infant's skin contact surface, was 39.7^0 C (103.5^0 F) at 15 minutes of which the peak temperature was 41.0^0 C (105.8^0 F).*

Conclusion: *The cereal-grain WP, when used along with traditional nursing interventions as a heat source during newborn transport, should be safe with careful handling. It should be heated in the microwave oven exactly for one minute. A towel is placed above an A4-size brown envelope with the WP inside and the bundled infant is placed on it. Remove the towel at 35 minutes and lay the bundled infant on the brown envelope. It should be effective and safe in providing a warm transport for at least 2 hours since the temperature of the WP at the towel representing skin contact surface is not higher than 42^0 C (107.6^0 F) and there is no risk for hot water leakage.*

Keywords: *Hypothermia, Heat source, Hot water bottle, Newborn transport, Warming pad, Cereal grain, Burn*

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Hypothermia is a common problem in neonates, particularly in developing countries where it is an important contributory factor to neonatal mortality and morbidity[1]. Neonates are at higher risk for hypo-

thermia if they need to be transferred to hospital, or to another section of a hospital such as the postnatal ward or neonatal care unit. As a result, WHO has issued a guide explaining the principles and methods for preventing and treating hypothermia of which ensuring warm, safe transport, if necessary, is one of the recommendations[1,2].

In Thailand all 719 district hospitals throughout the nation and most provincial hospitals lack transport incubator due to its high cost. Traditional nursing interventions have been developed to limit the infant s heat loss. These include a two-layered cap and bootee worn by the infant, a plastic sheet covering the infant to diminish evaporative and convective heat losses and wrapping it in a blanket or bundling it with a thick towel. With these interventions, especially when environmental temperature is low or transport time is long, hypothermia is still unpreventable unless there is an adequate heat source. Hot water bottles are routinely used in Thai clinical settings. Applications of hot water bottle have been complicated by scald when there is an accidental leak of the hot water or contact burn from its inherent hot surface[3,4]. Furthermore, in hospitals equipped with modern transport incubators, their uses also have limitations in their ability to keep infants euthermic when transports made in cold weather and in very low birth weight infants or when hand bagging is required[2]. As a result, skin-to-skin contact with the mother (kangaroo transport) has been recommended[1,5]. When kangaroo transport is not possible or using transport incubator in cold weather, an effective and safer heat source has to be sought.

This study describes a low cost and appropriate technique for developing countries in warming infants during transport by using a warming pad (WP) filled with mung beans or dry corn used in feeding livestocks as a heat source to achieve better thermal control of neonates for a safer transport. The first purpose of this study was to determine which cereal grain, when heated in the microwave oven, was warmer and the length of time that it was warm. A second purpose was to investigate the optimal heating time for the WP in clinical application by measuring the temperature of the WP when heated in the microwave oven for 1, $1^1/_2$ and 2 minutes. A third purpose was to assess the temperature of towel used to bundle the newborn representing the skin contact surface to prevent skin thermal injury if there was an excessive temperature.

Materials and Methods

Assessment of cereal-grain WP was conducted in four parts.

Part 1

The WP was made of a strong-cotton-cloth bag (the fabric for making jeans) with a size of A4 paper sheet (210 x 297 mm). The bag was filled with one kilogram of either mung beans or dry corn (used in feeding livestocks). The WP was put in a 800-watts microwave oven set at maximal het for two minutes. The grains were thoroughly mixed to distribute heat evenly and then placed in a disposable A4-size brown envelope to prevent contamination in clinical use (Fig. 1). The brown envelope with the WP inside was then assessed. A temperature probe was attached at the center of the outer surface of brown envelope to monitor the temperature continuously. The temperature was recorded every 5 minutes for 120 minutes to assess the maximal temperature and the length of time that the warming pad remained warm.

Part 2

The WPs were heated in the microwave oven for 1, $1^1/_2$ and 2 minutes to investigate the optimal warming time in clinical application. Data collection was followed the process performed in Part 1.

Part 3

This part was to imitate Thai clinical practice when a newborn is transported. Newborn is usually dressed with one layer of regular clothing and bundled with a thick towel (62 x115 cm) and lies on the hot water bottle. When tested, the brown envelope with the WP inside was covered with a towel with a temperature probe attached to the towel at the center of the warming pad. The temperature of towel on the side representing the skin contact side was monitored and recorded as performed in Part 1 to evaluate the maximal temperature when the warming pad was heated in the microwave oven for 1, $1^1/_2$ and 2 minutes.

Part 4

To detect the dangers of any warming devices as warm as 42 ^{0}C (107.6 ^{0}F) that can possibly burn an infant, the warming pad heated for one minute in the microwave oven was covered with another towel. The temperature of the second layer of towel was measured and recorded as the steps described in Part 1.

All temperature measurements were continuously monitored by Duotemp TM101 Temperature Monitor, Fisher & Paykel Healthcar Limited, Auckland, New Zealand. The two Duotemp Temperature Monitors were calibrated before the experiment.

Data were analyzed by SPSS for Windows Version 11.0 (Chicago, Illinois). Temperatures were expressed as mean, standard deviation and range. The differences between mean temperatures of mung bean and corn warming pads at every corresponding time were tested by two-tailed independent t-test.

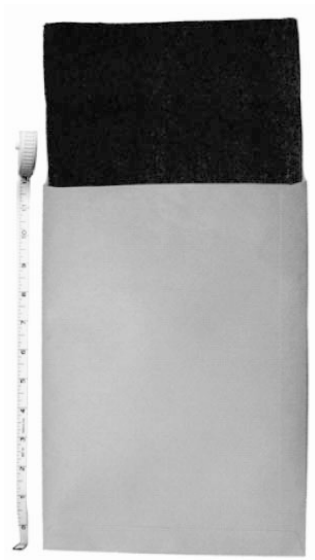

Fig. 1 The cereal-grain warming pad placed in a A4-size brown envelope

Results

The assessment of cereal-grain WPs was shown in Figure 2 and Table 1. The mean room temperature (range) where the experiment was conducted was 30.5^0 C (26.0-32.7^0 C). There was no statistical difference of all measurements between the two WPs at any corresponding time. The peak temperature was 51^0 C (123.8^0 F) measured at 5 minutes, maintained for 10 minutes and then began to decrease. At 120 minutes the mean temperatures were 35.9^0 C (96.6^0 F) and 35.6^0 C (96.0^0 F), respectively. These temperatures were higher than room temperature by 5^0 C (41^0 F).

The maximal mean temperatures of the warming pads, displayed in Table 2, varied in proportion to the time used in heating in the microwave oven. The mean maximal temperatures of the first layer of towel covering the warming pads heated in the microwave oven for 1, 1.30 and 2 minutes and that of the second layer of towel covering the warming pad warmed in the microwave oven for 1 minute were shown in Table 2. The maximal mean temperatures of the towels varied proportionately with the temperatures of the warming pads. At 2 hours after warming, the towel temperatures were still higher than the room temperatures.

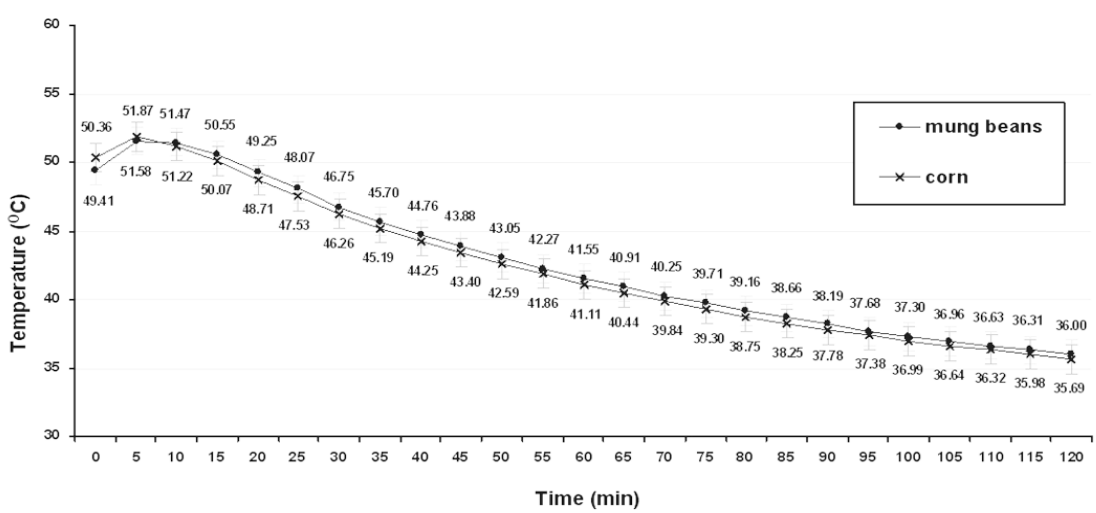

Fig. 2 Mean temperatures (SD) of the warming pads during 120 minutes of assessment

Table 1. The mean temperature and standard deviation of the warming pads

Time after warming (min)	Temperature of warming pad (^{0} C)		P-value
	Mung bean (n = 31)	Corn (n=31)	
5	51.58* (1.8)	51.87* (1.9)	.55
30	46.7(1.6)	46.2(1.5)	.48
60	41.5(1.2)	41.1(1.3)	.43
90	38.1(1.2)	37.7(1.3)	.23
120	35.9 (1.0)	35.6 (1.1)	.30

* maximal temperature

Table 2. Mean maximal temperatures (SD) of warming pads and towel with different heating times

Time of warming in the microwave oven (min)	1 (n=10)	$1^1/_2$ (n=10)	2 (n=10)
Mean Room temperature (^{0}C)	30.3(1.0)	30.4 (0.8)	31.0 (2.0)
minimum-maximum	28.8-31.4	29.6-31.4	27.5-32.9
Cereal-grain warming pad			
Maximal temperature (^{0}C)	44.3 (0.9)	49.1 (2.0)	54.7 (2.6)
minimum-maximum	42.7-45.4	46.5-52.3	51.0-58.7
Temperature at 2 hours (^{0}C)	36.6 (1.1)	39.0 (1.7)	41.3(4.6)
minimum-maximum	34.1-38.2	36.3-41.2	36.9-48.6
Towel			
Maximal temperature (^{0}C)			
At 1st layer (close to the warming pad)	42.4 (1.2)	44.7 (2.5)	46.4 (2.1)
minimum-maximum	40.3-44.3	39.7-48.8	43.3-50.8
At 2nd layer	39.8 (1.0)	-	-
minimum-maximum	37.8-41.0		
Mean temperature at 2 hours (^{0}C)			
At the 1st layer	35.6 (1.1)	36.8 (1.6)	38.5 (2.7)
minimum-maximum	33.4-37.1	34.3-38.6	35.0-43.2
At the 2nd layer	34.4 (1.1)	-	-
minimum-maximum	32.4-36.1		

The mean maximal temperatures of the towels covering the brown envelope with WP inside heated in the microwave oven for 1 minute were depicted in Figure 3. At the first layer, the mean temperature reached 42^0 C (107.6^0 F) in 10 minutes after warming and was maintained $\geq$ 42^0 C for 10 minutes. All temperature measurements at the first-layer towel was $\leq$ 42^0 C at 35 minutes after warming. At 2 hours after heating the mean temperature of the towel was 35.6^0 C (96.1^0 F) which was higher than room temperature by 5.3^0 C (41.5^0 F). The maximal mean temperature at the second-layer towel was 39.7^0 C (103.5^0 F) at 15 minutes of which the peak temperature was 41.0^0 C (105.8^0 F).

Discussion

The uneven heating by microwave oven, hot on the outside but cool in the middle, was shown in the pilot study when 1.5 kg compared to 1 kg of cereal grain was used for the warming pad. It resulted in a more unevenly distributed temperature and a lower temperature at the surface when the cereal grains were

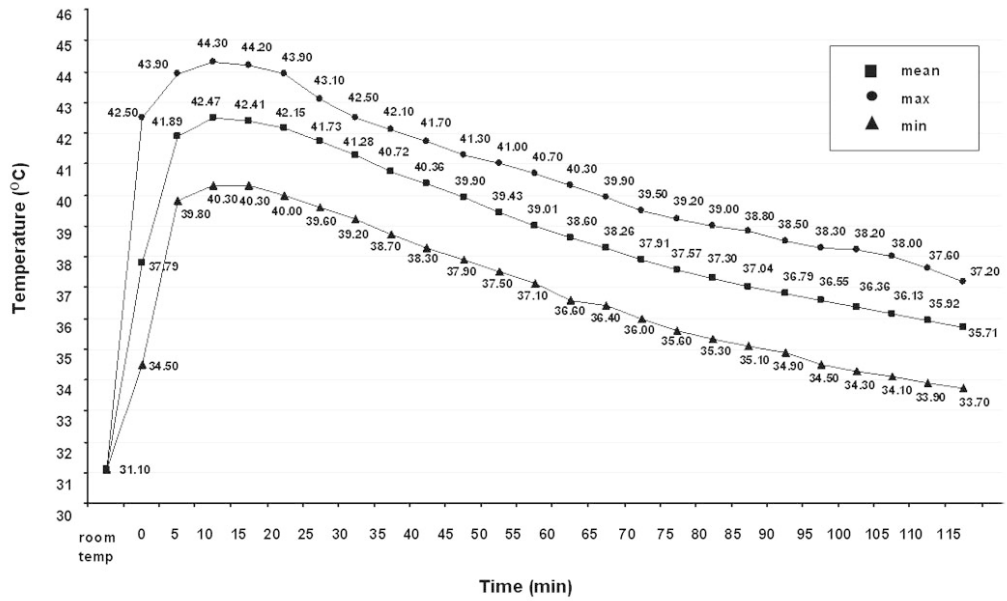

Fig. 3a. The mean temperatures (range) of the first towel covering the brown envelope with the warming pad inside heated in the microwave oven for 1 minute

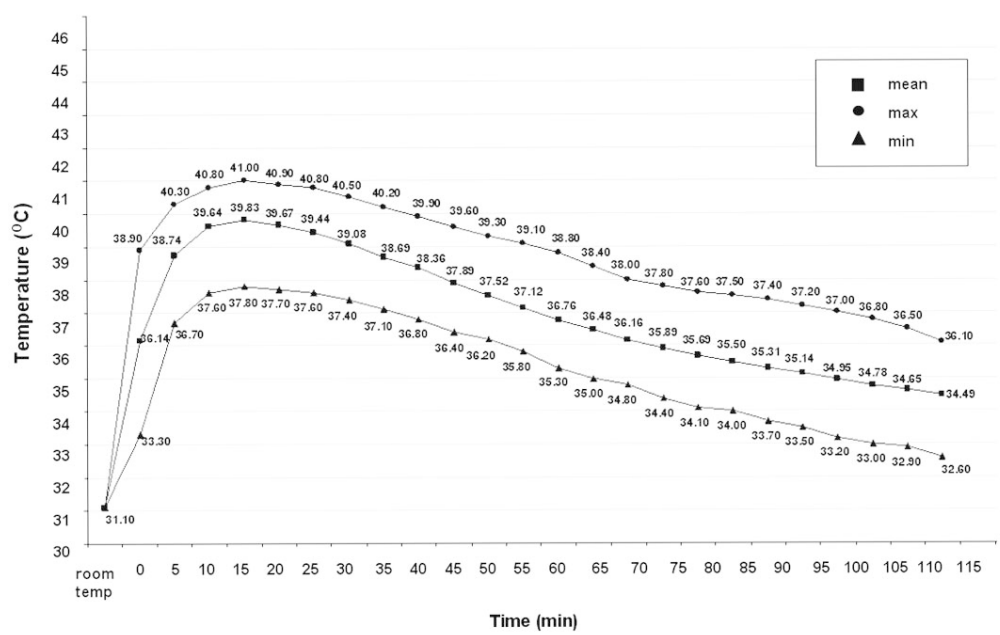

Fig. 3b. The mean temperatures (range) of the second towel representing the skin contact surface when the warming pad heated in the microwave oven for 1 minute

mixed thoroughly. From this evidence, the cereal grain in the warming pad was reduced to one kilogram and, before testing, mixed thoroughly after heated.

Accidental skin burns from hot water bottle without careful handling in neonatal use, contact with its hot surface or hot water from a leak, have been reported[3,4]. Diller has stated that thermal injuries to living tissue occur as a function of temperature and the duration exposed to the heat source[6]. Moritz et al. have investigated the effects on human skin and animals on episodes of hyperthermia of varying duration and of varying degrees of intensity. They found that a 6-hour contact time with a surface temperature of 44^0 C (111.2^0 F) was sufficient to induce a complete epidermal necrosis. Such amount of time was reduced to 9.5 minutes for a surface temperature of 49^0 C (120.2^0 F) and 0.5 minute for 55^0 C (131^0 F)[7]. Diller expected by extrapolating from the available data that a surface temperature of 42^0 C (107.6^0 F) to 43^0 C (109.4^0 F) could induce a second-degree burn on the skin after a period of 12 to 20 hours[8]. From these evidences, Mohrenschl-ager et al, stated that only those warming devices with a surface temperature below 42^0C (107.6^0 F) should be applied to newborn. If the surface temperature cannot be measured, the warming bottle should not be used[4].

Despite transport with specialized equipment and trained personnel with advanced skill, the infants may arrive in the referral centers with subnormal temperatures[9,10]. Nielsen et al. and L Herault et al, evaluated the effectiveness of transport thermal mattress (TTM) in stabilizing and maintaining body temperature during newborn transport. TTM produces heat via crystallization reaction that emits thermal energy when exposed to the catalyst. The mattress was heat activated to 40.0^0 C (104^0 F) within one minute after initiating the reaction. The data have supported the benefit of using TTM adjunct to the transport incubator for keeping newborns warm during transport[9,10].

The results of this assessment have shown that cereal-grain WPs, both mung beans and dry corn, are equally effective in emitting heat when warmed in the microwave oven. They can be used along with traditional nursing interventions as a heat source during newborn transport. It should be safe with careful handling by following the guideline of using. Heat the WP in the microwave oven exactly for one minute. Place a towel above the A4-size brown envelope with the WP inside. Lay the bundled infant on the towel. Remove the towel at 35 minutes and then lay the bundled infant on the brown envelope. It should be effective and safe in providing a warm transport for at least 2 hours since the temperature of the WP at the towel representing skin contact surface is not higher than 42^0 C (107.6^0 F) and there is no risk for hot water leakage. This warming pad can also be used as a supplemental heat source for warming the infant or incubator in the process of transport when transport made in cold weather since transport incubators have limitations in the ability to keep infants euthermic.

There is no limitation in using cereal-grain warming pad in all hospitals in Thailand since microwave oven is an inexpensive appliance and available in almost all hospitals in the Kingdom. It offers the advantages of being easily adopted, inexpensive and reusable. Its hazard to the skin can be prevented by careful handling and following strictly all the handling process mentioned in this study.

Conclusion

Cereal-grain warming pad can be used as a heat source during newborn transport. It is easily adopted, inexpensive and reusable. It is modified to compensate for lack of transport incubator and commercial transport thermal mattress and used along with incubator when transport made in cold weather or in very low birth weight infants. It can offer a warm and safe newborn transport used in conjunction with traditional nursing interventions.

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การประเมินถุงผ้าบรรจุธัญพืชเป็นแหล่งให้ความร้อนแก่ทารกขณะเคลื่อนย้ายทารก

เกรียงศักดิ์ จีระแพทย์, วีณา จีระแพทย์

จุดประสงค์: *เพื่อหาแหล่งให้ความร้อนที่ปลอดภัย (อุณหภูมิของพื้นผิวที่สัมผัสทารกไม่เกิน 42^0 ซ) ราคาถูก หาได้ง่าย และไม่เสี่ยงต่อการรั่วออกมาลวกทารก เพื่ออุ่นทารกแรกเกิดขณะเคลื่อนย้าย และทดแทนการขาดตู้อบทารกชนิดสำหรับเคลื่อนย้ายหรือใช้เป็นแหล่งให้ความร้อนเสริมในการเคลื่อนย้ายทารกด้วยตู้อบในฤดูกาลที่อากาศเย็นมาก*

วัสดุและวิธีการ: *ใช้เมล็ดถั่วเขียวหรือเมล็ดข้าวโพดสำหรับเลี้ยงสัตว์ น้ำหนัก 1 กก. บรรจุในถุงผ้าสำหรับตัดกางเกงยีน ขนาดเท่ากระดาษ A4*

ขั้นตอนการทดสอบ: *ขั้นตอนที่ 1 ศึกษาธัญพืชที่เหมาะสมสำหรับนำมาบรรจุในถุง โดยทดสอบความแตกต่างของอุณหภูมิและระยะเวลาของเก็บความร้อนของถุงบรรจุถั่วเขียวหรือข้าวโพด โดยอุ่นถุงบรรจุธัญพืชในเตาไมโครเวฟด้วยกำลัง 800 วัตต์ ด้วยความร้อนสูงสุด นาน 2 นาที ขยำธัญพืชในถุงผ้าให้เข้ากัน เพื่อให้ความร้อนกระจายทั่วและเท่าถึงกัน บรรจุถุงธัญพืชที่อุ่นไว้ในซองกระดาษสีน้ำตาลขนาด A4 เพื่อป้องกันการปนเปื้อนจุลินทรีย์ติดตัวรับรู้อุณหภูมิไว้ที่กึ่งกลางซองกระดาษและบันทึกอุณหภูมิทุก 5 นาที นาน 2 ชม.*

ขั้นตอนที่ 2 ศึกษาเวลาที่เหมาะสมสำหรับอุ่นถุงธัญพืชในเตาไมโครเวฟ ที่ให้อุณหภูมิพอเหมาะสำหรับใช้ในการอุ่นทารกขณะเคลื่อนย้ายทารก โดยทดสอบอุณหภูมิและระยะเวลาของการเก็บความร้อนของถุงธัญพืชที่อุ่นด้วยเตาไมโครเวฟ กำลัง 800 วัตต์ นาน 1, 1, $^1/_2$, 2 นาที แล้วติดตามและบันทึกอุณหภูมิทุก 5 นาที นาน 2 ชม.

ขั้นตอนที่ 3 ศึกษาความปลอดภัยเมื่อนำไปใช้ในคลินิก ซึ่งแหล่งให้ความร้อนต้องมีอุณหภูมิพื้นผิวที่สัมผัสทารกไม่เกิน 42^0 ซ โดยเปรียบเทียบอุณหภูมิผ้าขนหนูที่วางบนซองกระดาษสีน้ำตาลขนาด A4 ภายในมีถุงบรรจุธัญพืชที่อุ่นด้วยเตาไมโครเวฟ กำลัง 800 วัตต์ นาน 1, 1, $^1/_2$, 2 นาที วัดและติดตามอุณหภูมิ ผ่านตัวรับรู้อุณหภูมิ ซึ่งติดไว้บนผ้าขนหนูตรงกับจุดกึ่งกลางของซองกระดาษและถุงธัญพืช ทุก 5 นาที นาน 2 ชม.

ขั้นตอนที่ 4 เมื่อทราบว่าถุงธัญพืชที่อุ่นในเตาไมโครเวฟนาน 1 นาที ให้อุณหภูมิที่เหมาะสมที่สุด แต่อุณหภูมิที่ผ้าขนหนู 1 ชั้น ยังสูงกว่า 42^0 ซ จึงศึกษาอุณหภูมิที่ผ้าขนหนูชั้นที่ 2 ที่ปูบนผ้าขนหนูผืนที่ 1 โดยติดตามและบันทึกอุณหภูมิตามขั้นตอนที่ 1

ผลการศึกษา: *ถุงผ้าที่บรรจุถั่วเขียว หรือข้าวโพด 1 กก. ให้อุณหภูมิเฉลี่ยสูงสุดเท่ากัน และไม่มีความแตกต่างทางสถิติของอุณหภูมิที่เปรียบเทียบในเวลาเดียวกันตลอด 2 ชั่วโมง อุณหภูมิเฉลี่ยที่วัดที่ 2 ชั่วโมงสูงกว่าอุณหภูมิห้องที่ทำการศึกษา 5^0 ซ*

ถุงผ้าธัญพืชที่อุ่นในเตาไมโครเวฟ ด้วยกำลัง 800 วัตต์ นาน 1 นาที แล้วบรรจุในซองกระดาษน้ำตาล A4 และปูทับด้วยผ้าขนหนูหนา 2 ชั้น จะให้อุณหภูมิที่พอเหมาะและปลอดภัยที่สุด โดยอุณหภูมิเฉลี่ยของผ้าขนหนูชั้นที่ 1 ซึ่งอยู่ชิดกับซองกระดาษสีน้ำตาลที่มีถุงธัญพืชอยู่ภายในเท่ากับ 42^0 ซ ที่ 10 นาที หลังนำออกจากเตาไมโครเวฟ และสูงกว่า 42^0 ซ นาน 10 นาที ที่ 35 นาทีหลังอุ่นมีอุณหภูมิ $\leq 42^0$ ซ และที่ 2 ชั่วโมง อุณหภูมิเท่ากับ 35.6^0 ซ ซึ่งสูงกว่าอุณหภูมิห้อง 5.3^0 ซ อุณหภูมิเฉลี่ยสูงสุดที่ผ้าขนหนูชั้นที่ 2 เท่ากับ 39.7^0 ซ ที่ 15 นาที โดยมีอุณหภูมิสูงสุด เท่ากับ 41.0^0 ซ

สรุป: *ถุงผ้าบรรจุธัญพืชสามารถใช้เป็นแหล่งให้ความอบอุ่นแก่ทารกขณะเคลื่อนย้าย เมื่อต้องการใช้ ให้อุ่นถุงธัญพืช ในเตาไมโครเวฟที่ตั้งกำลัง 800 วัตต์ นาน 1 นาที ขยำธัญพืชในถุงผ้าให้เข้ากัน บรรจุถุงผ้าไว้ในซองกระดาษสีน้ำตาล ปูผ้าขนหนูบนซองสีน้ำตาล 1 ชั้น ห่อทารกด้วยผ้าขนหนูผืนที่สอง แล้ววางทารกนอนบนผ้าขนหนูผืนที่ 1 ที่มีถุงธัญพืชอยู่ข้างใต้ ภายหลัง 35 นาที ให้นำผ้าขนหนูผืนที่ 1 ออก แล้วให้ทารกที่ห่อด้วยผ้าขนหนูนอนบนซองสีน้ำตาลต่อไป*