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Food Package Design to Preserve Food Temperature

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***Abstract*—**It is desirable that most human food is warm when eaten, including when food is obtained by taking it away from the point of sale in disposable food packaging. However, such packaging does not retain heat for a long time, which is necessary to ensure the food remains warm when eaten. The study looked for single-use food packaging that could retain the heat of the food for a long time. The methodology for obtaining such packaging is either by modifying available packages on the market or by making new ones with materials that are easily obtained locally, then testing by loading the local food and measuring its temperature and the length of time until it reaches the lowest acceptable temperature for hot food (56°C). Packages made of plastic boxes lined with thin aluminum foil on the inside are the best way to keep food warm for up to 44 minutes from the time it is put in the package to the time the required temperature is reached. Moreover, packaging made of local common food paper, where the food was put in a transparent plastic bag inside the package, was found to be the simplest package that could retain heat for 82.31% as long as the best packaging could, in this study. Plastic boxes with thin aluminum foil inside were the best single-use food packaging in this study that served to keep hot food warm and fit for consumption.

***Keywords*—**Aluminum foil, hot food, local food, packaging.

I. Introduction

HUMANS are thought to have survived in many ways. One of the ways is by consuming a portion of food to get the energy to live [1]. In order to consume food, humans use raw food (mixed with other ingredients), treat it by heating in an oven, or just by spreading spices on it, or just by cooling it and eating it [2], [3]. Sometimes, they even use food processing [4]. In order to process food, there are several techniques. Some examples are frying, baking, smoking, and heating [5].

Suppose the food contains energy, and its thermal effect depends on the amount of that energy plus the combined energy cost of consuming and digesting it. In that case, it should follow that adding energy to the food by heating it ought to have a relatively direct additive effect on the food's thermal value. Conversely, cold food ought to minimize the thermal effect of eating [6], and that temperature can be an essential variable in flavor perception [7].

When consuming take-away food in hot or cold condition, it is important to consider whether it has been safely handled. Hot food must be kept hot and cold food must be kept cold [8]. However, there are reasons why people choose to eat food in a warm condition. Since heating food unlocks calories and nutrients, this may be preferable to eating raw food. In addition, hot food emanates many more airborne particles than does cold food. Since a large part of our taste sensation also involves smell, hot food would positively reinforce its selection [9]. Furthermore, this intuition regarding warm food is important for marketers and managers because warm-food temperatures can increase willingness to pay (by 25%) and the amount served (by 27%), as well as influence consumer preferences [10].

To maintain food temperature, people use aluminum foil, special bags, thermos containers, or other means. In this paper, aluminum foil is used as a material to preserve food temperature. With present toxicological knowledge, aluminum in packaging material is considered safe, and inner-coating using foil is recommended in specific cases [11]. Therefore, a package was designed that can maintain food temperature by adding a layer of aluminum foil.

There are several ways to measure the temperature [12]. A single-use food package was designed, and the food temperature inside the package was measured using type-K thermocouples. This type of sensor measures the ambient temperature inside the food package. Type K is the most common type of thermocouple. It is inexpensive, accurate, reliable, and has a wide temperature range with an accuracy standard of 2.2 °C or 0.75% and error limits of 1.1 °C or 0.4% [13].

In this paper, the parameters of the designed food package will be described briefly. The design will determine the ambient temperature inside the package (in which has been placed a particular type of food) by using a thermocouple as a sensor. The longest recorded time that the ambient temperature is preserved inside the food package will determine the best design.

II. Method

A. Making the Food Package

Several types of single-use food packages were made in this experiment, with three types of materials as the outer layer of the package: cardboard, plastic boxes, and food paper. Two types of aluminum foil were used for the inner layer, a thin type and a woven type, the latter being more expensive. Transparent plastic bags were also used. The plastic boxes as the outer layer of the package were purchased without modification, and then the aluminum foil was placed inside. In coating with aluminum foil, there is a difference between the thin and woven types. The thin type is cut to size and attached to the inner surface of the plastic box using food-grade glue. The cardboard is susceptible to liquids and the food paper even more so, if used in direct contact with the food. Therefore, plastic bags were used to accommodate the food

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inside the package that was tested without aluminum foil as its inner layer.

In contrast, the woven type of foil was cut to size and bonded using electric heat pulses without air leakage in the bonding. Meanwhile, the other materials (cardboard and food paper) for the outer layers were purchased in sheets. Then, the aluminum foil was glued together using wet glue and shaped, as designed previously, by folding and gluing to fit the package.

B. Measuring the Food Temperature

To process the chicken, a local restaurant half-fried chicken at the venue and then completed the frying at a location near the laboratory where the measurements would take place. Meanwhile, tempe and tofu were fried near the laboratory. All the food was prepared in appropriate proportions. However, because the research fund was adjusted in view of the COVID-19 pandemic, the experiment was focused only on tofu as the food object (as seen in Fig. 1), as it is more affordable for most people. After the data logger and the computer were set and ready to measure temperature and record it, the food—consisting of 26 pieces of tofu per package—was fried and immediately placed into the designated packages. To monitor its temperature, one of the pieces of food was stabbed by a thermocouple. This process was done sequentially for the food and all the packages.

Fig. 1 A set of 26 pieces of tofu ready to be fried

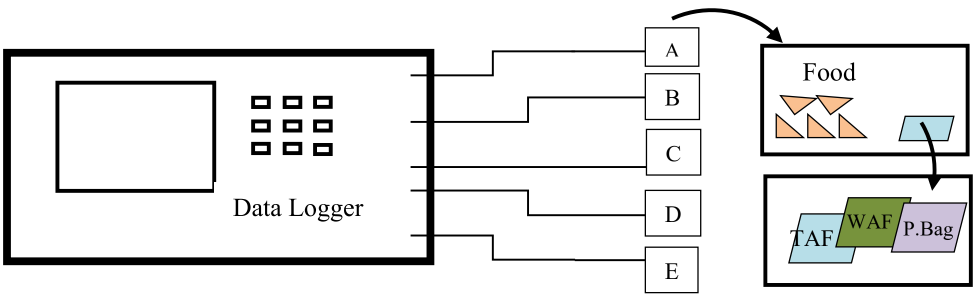


Fig. 2 Measurement method. A—E = Food package outer layer; TAF, WAF, Transparent Plastic Bag = Food package inner layer

TABLE I
TYPE OF PACKAGE AND PACKAGE CODE

No.	Type of Package	Package Code
1	Plastic box without aluminum foil	PB0
2	Plastic box with thin-film aluminum foil	PBTAF
3	Plastic box with woven*) aluminum foil	PBWAF
4	Food paper without aluminum foil	FP0
5	Food paper with thin-film aluminum foil	FPTAF
6	Food paper with woven aluminum foil	FPWAF
7	Thin cardboard without aluminum foil	NC0
8	Thin cardboard with thin-film aluminum foil	NCTAF
9	Thin cardboard with woven aluminum foil	NCWAF
10	Thick cardboard without aluminum foil	KC0
11	Thick cardboard with thin-film aluminum foil	KCTAF
12	Thick cardboard with woven aluminum foil	KCWAF
13	Brown cardboard without aluminum foil	BC0
14	Brown cardboard with thin-film aluminum foil	BCTAF
15	Brown cardboard with woven aluminum foil	BCWAF

*) In order to make this complete package, an electric plastic-sealer was used to glue the woven aluminum foil to the inside of the plastic box.

This research focuses on analyzing the data recorded to select which package kept the temperature of the food for the longest time, by monitoring the decreasing temperature in each package with the food inside. Fig. 2 is the measurement method inside the chamber. The ambient temperature of the chamber was 25 °C.

The package types and corresponding codes are presented in Table I.

The measurements were conducted sequentially, and every time the food temperature reached the ideal ("still good") temperature, which was 56 °C [14], the measurement was stopped. The temperature measurements were analyzed by normalizing[1] them and the maximum time to reach the minimum internal temperature requirement was determined.

[1] Normalizing here means that all temperature measurement data were started at the designated temperature and finished at the same safe food temperature.

III. Results and Discussion

The temperature measurement setup using thermocouples inside the packages is shown in Fig. 3. Each of the food packages has a code for identification. Below, in the diagrams, are the measurement results obtained from the packages and food.

Fig. 3 Example of the measurement setup of the food packages made of food paper and plastic boxes, with and without aluminum foil

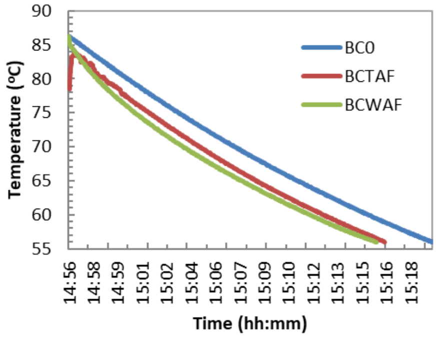
Because one of the highest starting-temperature measurements of the food was 86.2°C, the elapsed-time recording of the food temperature was conducted over the range of 86.2 °C to 56.0 °C. The duration that the food was kept in a warm condition (≥56 °C) that was achieved by each package is summarized in Table II, and the characteristics of temperature changes of the food in the designed take-away packages of the group with the same outer layer are shown in Fig. 4.

TABLE II
Tofu Inside the Various Package Types and Time Kept in Warm Condition

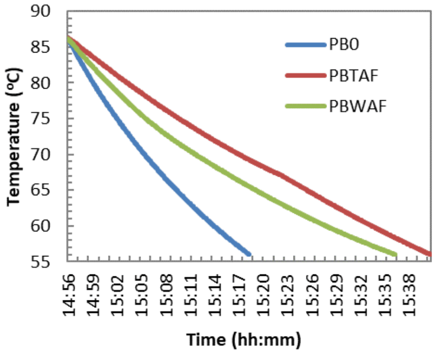
No.	Package Code	Time (min.)
1	BC0***)	22.9
2	BCTAF	19.56
3	BCWAF	19.24
4	PB0	22.0
5	PBTAF	44.04
6	PBWAF	39.42
7	NC0***)	38.1
8	NCTAF	35.07
9	NCWAF	39.11
10	FP0***)	36.25
11	FPTAF	34.22
12	FPWAF	37.22
13	KC0***)	31.47
14	KCTAF	38.45
15	KCWAF	34.22

***) Because the outer layer of the package was paper, the tofu was placed inside a thin plastic bag to avoid paper damage caused by liquid that came from the hot tofu during temperature measurement.

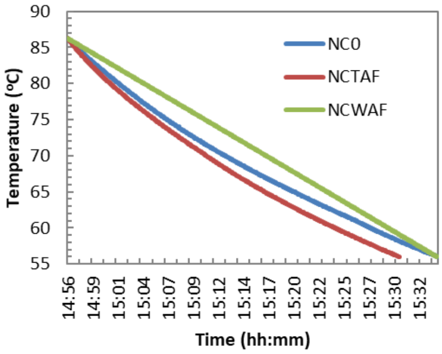
Based on the summarized data in Table II, the package made from a plastic box lined with thin-film aluminum foil (PBTAF) preserved the fried-tofu temperature longer than the other packages.



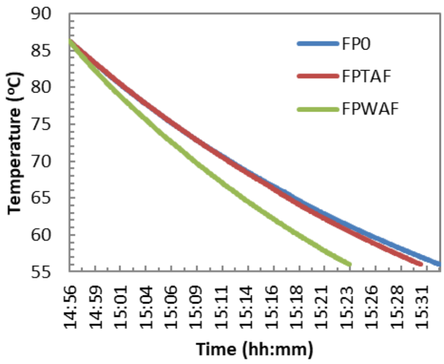
(a)



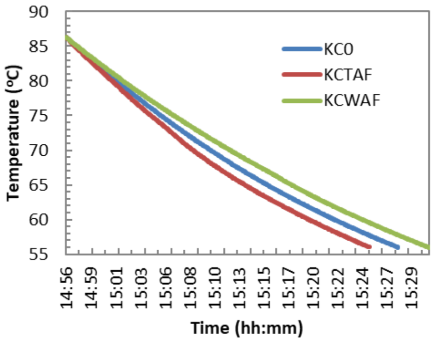
(b)



(c)



(d)



(e)

Fig. 4. The temperature characteristics of the tofu inside the grouped packages: (a) three types of brown cardboard (BC); (b) three types of plastic box (PB); (c) three types of thin cardboard (NC); (d) three types of food paper (FP); (e) three types of thick cardboard (KC)

Table II and Fig. 4 show that (1) the PBTAF had the longest preservation time, keeping the tofu warm for 44.04 minutes with (on average) the temperature decreasing at 0.835 13°C/min. at the start and 0.525 75°C/min. at the end, and (2) the FP0 had a reasonable preservation time, keeping tofu warm for 36.25 minutes while using the cheapest materials and being easy to make.

IV. Conclusion

Based on the data measurements and calculations, the PBTAF single-use food package had the maximum time of temperature decrease, 44.04 minutes, while preserving the internal temperature requirement for safe food, although the PBWAF food package can also be considered good, with a time of 39.42 minutes but at a higher cost. However, the FP0 had the lowest cost and was the easiest to manufacture, keeping the food warm for 36.25 minutes—a reasonable preservation time.

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Sugiono was born in Tegal (Central Java), Indonesia, on August 23, 1955. He graduated from the Physics Department of the Bandung Institute of Technology, Bandung, Indonesia, with a Bachelor of Science degree in 1980, majoring in geometrical optics.

He designed and coordinated the making of military optical instruments such as night-vision tank periscopes, camera and pocket scopes, binoculars, long-range surveillance devices, rifle scopes, infrared target-aiming devices, radar-camera devices for vehicle-speed measurement, and crescent-moon telescopes. He had patents granted for: optical tools in vehicle-guiding safety features, optical marks for safety distances and optics-based tools acting as co-drivers, as well as being an ISO standards consultant for standards such as ISO 9001, ISO/IEC 17025, and ISO 15189. He was a senior executive of a personnel certification body of QMS auditors. He also wrote two books that were published: *Practical Guidance in Implementing Food Safety Assurance based on HACCP in Food Venues and Restaurants* (*Petunjuk Praktis Penerapan Sistem Jaminan Keamanan Pangan berbasis HACCP di Rumah Makan dan Restoran*) (Jakarta, Indonesia: LIPI Press, 2013) and *The Role of Optical Instruments in Cars* (*Peranan Instrumen Optik pada Mobil*) (Jakarta, Indonesia: LIPI Press, 2017). He also presented a paper titled *The Model of Inter-Vehicle Safe Distance Markings based on Mechanical and Optical Approach* (Jakarta, Indonesia: AMTEQ 2017). He has done previous research on keeping food hot for a longer time in one-use containers and is conducting current research on driving safety on toll roads.

Drs. Sugiono (Drs is the abbreviation of Doktorandus and is an old-style academic title in Indonesia for a four-and-a-half-year course of study in the university, carried out in the Dutch education system) is a member of the Researcher Community of Indonesia (Himpunan Peneliti Indonesia), the National Society of Standardization (Masyarakat Standardisasi Nasional), and is an Indonesian Community of Technology auditor.