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Optimisation of Cooking Time for Two Varieties of Foodstuffs using Single- and Double-Cavity Cooking Pots

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Abstract

The increase in the shortage of firewood due to deforestation, skyrocketing of electricity tariffs and fuel pump prices in recent times have propelled scientists to search for alternative measures of cooking that can reduce electric energy and fuel consumption. Double-cavity cooking pots have emerged in recent times to reduce the prolonged duration arising from the sequential cooking of different foodstuffs/ dishes using a single-cavity pot. However, experimental reports are rarely available to sensitise users about the advantages of using the double-cavity pot. The present work describes a simple and informative experimental report that compares the cooking time for two varieties of foodstuffs (rice and beans) using single- and double-cavity pots. It was found that the average time rate of cooking in the double-cavity pot was 1.33 °C/min less than in the single-cavity pot. The total time taken to concurrently cook equal masses of rice and beans in separate cavities of the double-cavity pot was found to be 9.98 min less than that of the single-cavity pot. The double-cavity pot proved to be economically viable by reducing the cooking time, electric energy, and fuel consumption that arise from the successional cooking of a variety of foodstuffs using the single-cavity pot.

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1. Introduction

Food is one of the necessities that sustain human life. Food for the human body is like fuel for engines that power vehicles. Without food, human beings cannot derive the energy needed to do physical and mental work. Most foodstuffs need to undergo processing by heat treatment, cooking, or mixing with other ingredients/ condiments under heating before it becomes consumable for human beings.

The quest for a balanced diet and good taste has, in the pasts few decades pushed mankind into nutritional research that has resulted in preparing different types of foodstuffs/ dishes that can be combined to make a nutritious and delicious meal. However, to sequentially (one after the other) prepare two or more varieties of foodstuffs for a meal is time, fuel (cooking gas), and energy (electrical energy) consuming. This is because, the first type of food would have to cook (get done) and be removed from the cooker/ burner, before the second type could be placed on the cooker to cook. This could result to time consuming. To solve this problem of time consumption, tabletop double-burner gas cookers and double-face electric hot plates/ cookers and induction cookers [1- 3] have emerged in the past few decades to enable the simultaneous (at once) cooking of two varieties of foods on two separate burners to save time. However, the double burners or cookers do not solve the problem of energy consumption because, the cooking fuel is being burned concurrently on the separate burners; or electric energy is being consumed simultaneously on the two separate heaters. To address this problem of fuel and energy consumption, research efforts have led to the discovery of relative cheap cookers such as solar cookers that utilize renewable solar energy [4], biogas derived from animal dung [5-8], and induction cookers that allow for fast heating/ cooking of food. The research efforts have succeeded in addressing either the challenge of time consumption only, or fuel and energy consumption only. None of the cookers have been able to simultaneously achieve the feat of time-, fuel-, or energy-saving.

Therefore, research is still ongoing in the search for the best cooking practices that can mitigate the challenges of time, fuel, and energy consumption. These research efforts have resulted in the emergence of different types of cooking pots, including the arctic cooking pot, clay pot, brazier, sauce pot, stock pot, fryer pot, pasta pot, dutch oven, double boiler which is also known as Bain Marie, double broiler pot, double-wall pot, multiple-zone cooking pot, and double-cavity pot (DCP) [9-18].

Pots are made using different materials. But the commonest pots are made from materials such as, stainless steel, copper, aluminum, cast iron, ceramic, glass, and clay, depending on the intended usage and economic value. Some manufacturers may also use more than one of these materials. Stainless steel pots are a popular choice for many cooks because of their availability and low cost. Aluminum pots are also common, especially in rural areas and poor households in Africa, and Nigeria in particular, due to their relatively light weight and low cost of the artisanal pots. Additionally, aluminum pots are desirable due to their good conductivity, which equate to lower usage of wood fuel, liquified petroleum gas fuel, and electric energy [19]. Aluminum pots are relatively cost-effective because it can be locally fabricated/ made by artisans using aluminum scraps littering our environment. Aluminum has a low melting point as compared to iron; hence, it can easily be used locally to fabricate pots without having to look for special heating devices to melt the source material.

The DCP (a cooking pot with two separate hollows/ cavities) can be a better alternative to the single-cavity pot (SCP, a cooking pot with a single cavity/ hollow) when the need to prepare two or more varieties of foods arises. For instance, to cook two varieties of foodstuffs such as rice (Oryza sativa) and beans (Phaseolus vulgaris) using the SCP implies that one of the foodstuffs would have to be cooked before the other in a successional manner. Or, to save time, the foodstuffs would be cooked in separate pots on the separate burners of a double-burner cooker. On the other hand, using the DCP means that the rice and beans would be cooked simultaneously in separate cavities of a DCP using a single-burner, thus achieving the advantages of time- and fuel-, or energy-saving at the same time. Therefore, the DCP has the dual economic values of time- and fuel- or energy-saving, unlike the double-burner cooker, biogas cookers and solar cookers, which can save either time or energy only at a time, but not both.

The DCP can be of great economic value in the present era of incessant increases in fuel pump price and electricity tariff in Nigeria and the world at large. Two varieties of foodstuffs can be cooked concurrently in the separate cavities of a DCP using a single burner to save time and energy. Cooking fuel or electric energy would be consumed by one burner, thereby reducing the fuel and energy consumption that may arise using two burners at the same time. Despite its great economic value, the DCP has been embraced/ accepted by a few households as cookware. The low patronage/ utilization of the dual-cavity cookware could be traced to poor sensitization and education of the populace about the advantages of the DCP over the SCP. The availability of experimental reports that can provide reliable data to sensitize the public about the advantages of deploying the DCP when engaged in cooking up to two or more varieties of foodstuffs is surprisingly, lacking in the literature.

Nevertheless**,** work is available for the evaluation of the influence of different cooking pot types on the metallic elemental content in edible chicken tissues [16]. Moya *et al.* [20] developed and validated a computational model for steak double-sided pan cooking. Hannami *et al.* [21] proposed a mathematical framework that models the heat transfer efficiency of cooking pots. Mathee and Street [19] described current insights and emerging evidence of health risks associated with artisanal aluminum pot making and usage. Pierce [17] investigated the potential cost and performance differences between plain and corrugated cooking pots. The workers performed a set of controlled experiments to document the manufacturing costs, cooking effectiveness, and vessel durability. Recently, Sutar *et al.* [18] conducted an experiment to investigate the best combination of pot size for common cooking processes such as heating milk, preparing tea and cooking rice. Surprisingly, literature report is scarce for the comparison of the cooking times for varieties of foods prepared using the SCP and DCP.

The present work attempts to provide for the first time a simple experimental report that compares the cooking time (time taken to cook a particular food) for an equal amount of rice and beans using the SCP and DCP. It was found that the average cooking time for beans using the SCP was approximately equal to the time required to concurrently cook an equal mass of beans and rice in separate cavities using the double-cavity pot. It was found that the current cooking of rice and beans in the separate cavities of a DCP could save up to 9.98 min as compared to the time taken to sequentially cook the two varieties of foods using the SCP.

2. Materials and Methods

2.1. Fabrication of the artisanal aluminum cooking pots

The artisanal aluminum cookware was forged using a variety of waste aluminum metal parts from vehicles, cans, construction materials, and household appliances [19]. Advanced DCP is scarce in the market – Makurdi, Benue State, Nigeria. Therefore, a local aluminum-works artisan was contracted to fabricate the two types of cooking pots needed for the experiment. The artisans in Nigeria employ the typical sand mold method to cast the aluminum cookware. The two types of fabricated pots had equal dimensions of hollow depth of 11.5 cm, width of 26.5 cm and thickness of 11.2 mm. The SCP had a cavity with a 4.31-liter-capacity. The DCP pot was made by dividing the 4.31-liter capacity pot into two equal halves such that each cavity had an equivalent capacity of 2.10 liters. The dividing wall had a thickness of 2.22 mm. The length and width of the pot were measured using a metre rule, while the thickness was measured using a Raider RDDDC 706 digital vernier calliper. Details of the typical production process are reported by Guma and Uche [22] and Osborn [23]. Figure 1 (a, b) show images of the fabricated DCP and DCP.

2.2. 2.2 Experimental investigation of cooking time using the SCP and DCP

A comparative experimental investigation into the cooking time for two varieties of foodstuffs follows: 400 g of rice in 700 cm^3 of water and 400 g of beans in 700 cm^3 of water were cooked sequentially using the SCP. In each case, the temperature rise was monitored every 2 min until the food became soft and in an edible state. The temperature was monitored using a UNISCOP mercury thermometer with the range -10 to 110 °C. The experiment was repeated using the DCP. 400 g of rice in 700 cm^3 of water was poured into Cavity 1, and the same mass of beans and the same volume of water were introduced into Cavity 2 of the DCP to achieve simultaneous cooking of the foodstuffs (Figure 1 (c)). The temperature was measured by inserting thermometers through the holes cut on the pot cover into the separate cavities (Figure 1 (d)). Being a kind of food that cooks faster, the rice became soft/ edible before the beans, therefore, it was scooped out of Cavity 1 to avoid overcooking. 500 cm^3 of water were introduced into Cavity 1 to prevent it from burning/ frying due to lack of moisture in it. Meanwhile, the beans continued to cook in Cavity 2 (of the DCP pot) until it became soft. In each case, the time taken for the rice and beans to cook was recorded. The temperature of beans was observed to drop slightly to 97 °C when room temperature water was introduced into Cavity 1 which initially contained rice. The quantity of heat supplied for all batches of cooking was kept constant by turning the nob of the gas supply line to the first calibration mark to ensure a moderate and equal heat supply (Figure 1 (e)). A flowchart of the experimental procedure is illustrated in Figure 2.

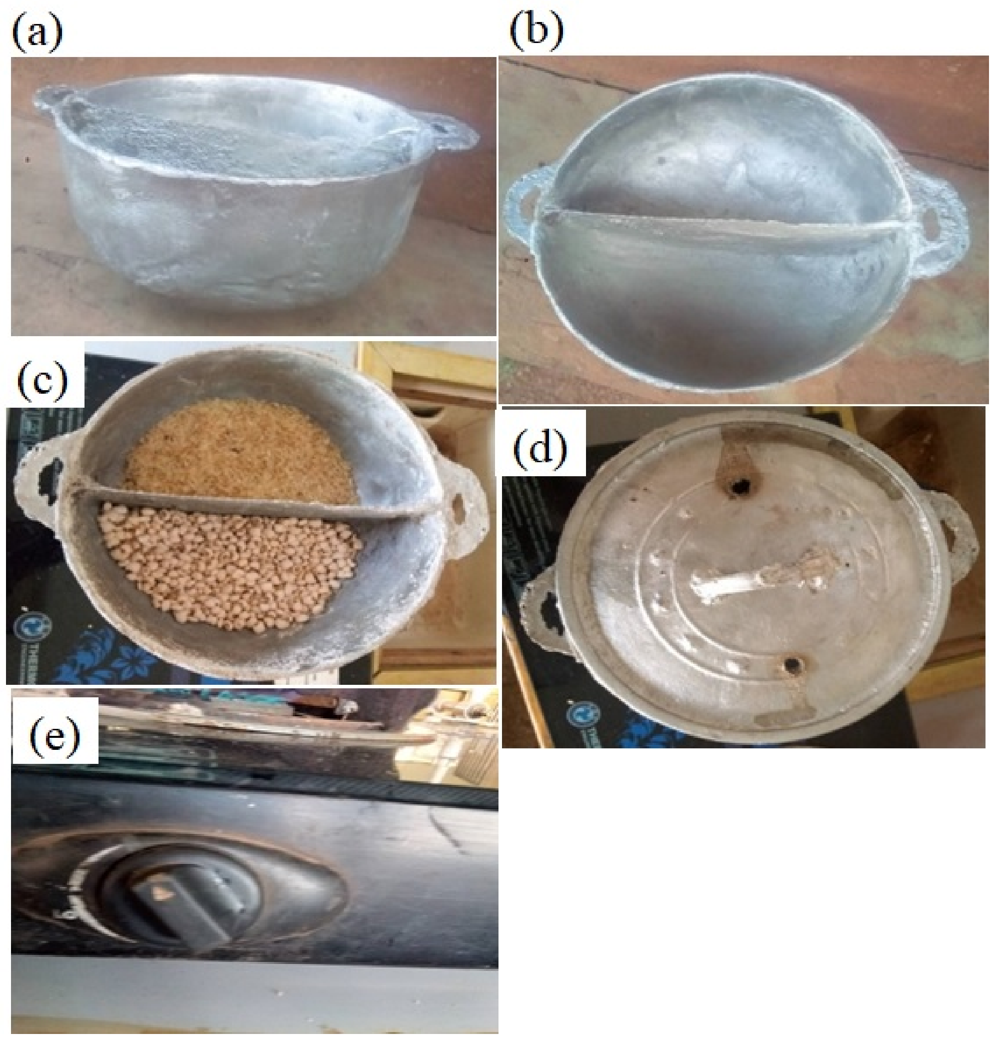

Figure 1. (a) Image of the SCP, (b) Image of the DCP, (c) DCP containing rice and beans in separate cavities, (d) DCP with cover, (e) Gas cooktop showing the constant nob setting for all batches of cooking

3. Results and Discussion

Figure 3 (a) shows the time rate of temperature increase when cooking 400 g of rice in 700 cm^3 of water using the SCP. A linear increase in temperature could be observed. The time rate of temperature increase (time rate of cooking) was found to be 8.7 °C/min, while the cooking time (time taken for the beans to cook, get done, become soft) was 13.05 min (Table 1). Figure 3 (b) demonstrates the time rate of temperature rise when cooking 400 g of beans in 700 cm^3 of water using the SCP. Similarly, a linear temperature increase could be observed. The time rate of temperature increase was found to be less than that of rice by a magnitude of 0.7 °C/min, while the cooking time for the beans was

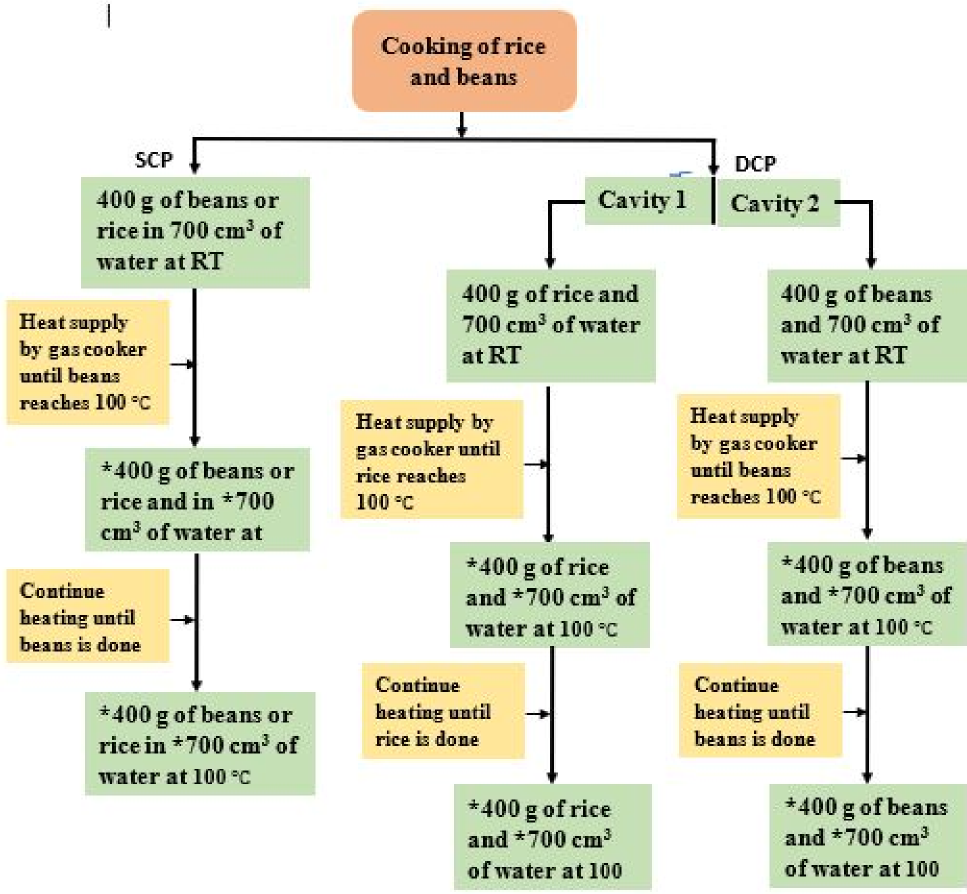

Figure 2. Flowchart of the experimental procedure for investigating the cooking time for two varieties of foodstuffs using the SCP and DCP.

greater than that of rice by a magnitude of 3.03 min. The disparity in the cooking rate and cooking time between rice and beans could be traced to the different specific heat capacities of the foodstuffs (0.789 kJ/kg.0C for rice, and 1.96 kJ/kg. for beans) [24, 25]. Generally, a food (beans) with a higher heat capacity would take longer to cook.

Figure 3 (c) demonstrates the time rate of temperature rise in the DCP: Cavity 1 contains 400 g of rice in 700 cm^3 of water, and Cavity 2 contains 400 g of beans in 700 cm^3 of water. The average time rate of cooking in the DCP was found to be less than that of the SCP by a magnitude of 1.678 and 0.978 °C/min for rice and beans, respectively. On the other hand, the cooking time for the various foodstuffs in the DCP was found to be significantly greater than that of the SCP by a magnitude of 2.18 min for rice and 3.07 min for beans. The significant disparity in the cooking rate and cooking time of the foodstuffs in the two types of pots could be attributed to the difference in the specific heat capacity of the two varieties of foods, and the increase in the total mass of substance (800 g, i.e., 400 g of rice and 400 g of beans) and volume of water (1400 cm^3, i.e., 700 cm^3 each in the separate cavities) contained in the DCP. It should be noted that heat and mass have a direct relationship. For instance, a large quantity of fuel will produce a higher heating effect as compared to a small quantity of the same type of fuel (fossil fuel, firewood, coal, etc.). Similarly, it takes longer to heat or raise the temperature of a large quantity of a substance as compared to a small quantity of the same substance under constant heating.

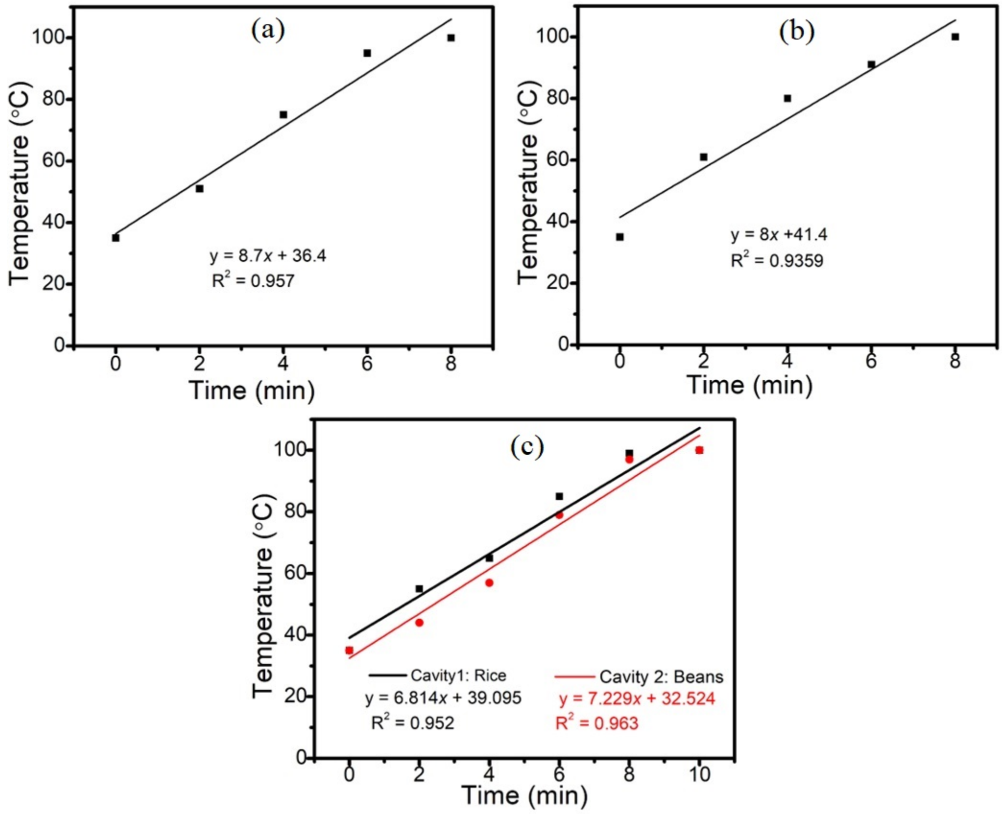

Figure 3. Time rate of cooking (a) 400 g of rice in 700 cm^3 of water using the SCP, (b) 400 g of beans in 700 cm^3 of water using the SCP, (c) 400 g of rice in 700 cm^3 of water and 400 g of beans in 700 cm^3 of water in separate cavities using the DCP.

Table 1. Comparison of the cooking rate and cooking time for rice and beans using the SCP and DCP

Type of pot	Cavity	Cooked substance	Mass of cooked substance (g)	Time rate of cooking (°C/min)	Average time rate of cooking (°C/min)	Cooking time (min)
SCP	SCP	Rice	400	8.700	8.700	13.05
SCP	SCP	Beans	400	8.000	8.000	16.08
DCP	1	Rice	400	6.814	7.022	15.23
	2	Beans	400	7.229	7.022	19.15

3.1. Justification of the DCP as the preferred option for cooking varieties of foodstuffs for a meal

The DCP is considered to be economical as compared to its counterpart when preparing two or more varieties of foods that are needed for a meal. This is because it took less time to cook two varieties of foods using the DCP (Table 1). The total time taken to sequentially cook rice and beans using the SCP was 29.13 min, which is 9.98 min greater than the time (19.15 min) it took to concurrently cook the foodstuffs in separate cavities using the DCP. The implication of the results is that additional fuel or energy would be used/ consumed when engaged in cooking the rice and beans sequentially using the SCP due to the prolonged cooking time/ duration. However, the DCP could reduce the time and fuel/ energy required by using the significantly short duration of 19.15 min to cook two varieties of foods simultaneously on a single burner. Another advantage of the DCP is that the food in Cavity 1 (rice), which cooked faster, could be scooped out and another type of foodstuff could be placed in this cavity to be cooking/ boiling while the food in Cavity 2 is getting ready/ done. When the food in Cavity 2 finally gets done, ordinary water can be introduced into the Cavity 2 to prevent it from frying due to lack of moisture until the second food in Cavity 1 gets done. Therefore, the use of the DCP can help solve the problem of energy and fuel consumption, which the double-burner cooker cannot address. The double-burner cooker addresses the problem of time-saving only.

4. Conclusion

In summary, the present work has attempted to provide a rare experimental report that compares the average time that is required to cook rice and beans using single- and double-cavity pots. It was found that the average cooking rate in the double-cavity pot was about 1.33 °C/min less than in the single-cavity pot. The total time taken to concurrently cook an equal mass of rice and beans in an equal volume of water in separate cavities using the double-cavity pot was found to be 9.98 min less than that of the single-cavity pot. The use of a double-cavity pot to simultaneously cook two varieties of foodstuffs was found to be economically viable in terms of time-saving and energy and fuel-saving. Therefore, households are encouraged to embrace the double-cavity cookware to reduce the time, electric energy, and quantity of fuel that is expended during the sequential cooking of varieties of foodstuffs which are needed for a meal.

References

[1] C. Svosve & L. Gudukeya, “Design of a smart electric cooking stove”, Procedia Manufact. **43** (2020) 135.

[2] S. Siddiqua, S. Firuz, B.M. Nur, R.J. Shaon, S.J. Chowdhury & A. Azad, “Development of double burner smart electric stove powered by solar photovoltaic energy”, IEEE Global Humanit. Technol. Conf. (2016) 1.

[3] J. Serrano, I. Lope, J. Acero, C. Carretero, J.M. Burdío & R. Alonso, “Design and optimization of small inductors on extra-thin pcb for flexible cooking surfaces”, IEEE Transact. Ind. Applic. **53** (2017) 371.

[4] P. P. Otte, “Solar cooking in Mozambique - an investigation of end-user’s needs for the design of solar cookers”, Energy Policy **74** (2014) 366.

[5] A. K. Kurchania, N. L. Panwar & S. D. Pagar, “Design and performance evaluation of biogas stove for community cooking application”, Intl. J. Sustain. Energy **29** (2010) 116.

[6] M. Rasoulkhani, M. Ebrahimi-Nik, M.H. Abbaspour-Fard & A. Rohani, “Comparative evaluation of the performance of an improved biomass cook stove and the traditional stoves of Iran”, Sustain. Environ. Res. **5** (2018) 1.

[7] C. L’Orange, J. Volckens & M. DeFoort, “Influence of stove type and cooking pot temperature on particulate matter emissions from biomass cook stoves”, Energy Sustain. Dev. **16** (2012) 448.

[8] T. Bond & M. R. Templeton, “History and future of domestic biogas plants in the developing world”, Energy Sustain. Dev. **15** (2011) 347.

[9] K. Harry & L. Frink, “The arctic cooking pot: why was it adopted?”, Amer. Anthrop. 111 (2009) 330.

[10] M. B. Schiffer, J. M. Skibo, T. C. Boelke, M. A. Neupert & M,.Aronson, “New perspectives on experimental archaeology: surface treatments and thermal response of the clay cooking pot”, Amer. Antiq. **59** (1994) 197.

[11] S. K. S. Cheng & R. Tarenga, “Double wall cooking vessel.” United States Patent 7,097,064 B2 (2006) 1.

[12] H. Schultz, “Double-walled cooking pot.”, United State Patent 5,348,187 (1995) 1.

[13] P. Kadam & J. P. Shete, “Experimental study of heat transfer characteristics and thermal efficiency of different cooking pots”, Intl. J. Scient. Dev. Res. **2** (2017) 121.

[14] G. Ronda, “Quick-cooking pot.” United States Patent 6,723,963 B2 (2004) 1.

[15] P. C. Schirmer, “Multi-heating zone cooking pot.” United States Patent 6,035,766 (2000) 1.

[16] N. S. Campos, F. B. M. Alvarenga, C. M. Sabarense, M. A. L. Oliveira, J. G. Timm, M. A. Vieira & R. A. Sousa, “Evaluation of the influence of different cooking pot types on the metallic elements content inedible chicken tissues by MIP OES”, Braz. J. Food Technol. **23** (2020) 1.

[17] C. Pierce, “Reverse engineering the ceramic cooking pot: Cost and performance properties of plain and textured vessels”, J. Archaeol. Meth. Theory **12** (2005) 117.

[18] K. B. Sutar, M. Kumar, M. K. Patel & A. Kumar, “Experimental investigation on pot design and efficiency of LPG utilization for some domestic cooking processes”, Energy Sustain. Dev. **56** (2020) 67.

[19] A. Mathee & R. Street, “Recycled aluminium cooking pots: a growing public health concern in poorly resourced countries”, BMC Public Health **20** (2020) 1.

[20] J. Moya, S. Lorente-Bailo, M. L. Salvador, A. Ferrer-Mairal, M. A. Martínez, B. Calvo & J. Grasa, “Development and validation of a computational model for steak double-sided pan cooking”, J. Food Eng. **298** (2021) 1.

[21] S. Hannani, E. Hessari, M. Fardadi & M. Jeddi, “Mathematical modeling of cooking pots’ thermal efficiency using a combined experimental and neural network method”, Energy **31** (2006) 2969.

[22] T. N. Guma & O. L. Uche, A typification of foundry practices for correct artisanal sand casting of aluminum pots, International Journal of Engineering Applied Sciences and Technology **4** (2019) 169.

[23] E. L. Osborn, “Casting aluminium cooking pots: labour, migration and artisan production in West Africa’s informal sector, 1945–2005”, African Ident. **7** (2009) 373.

[24] C. Marella, K. Muthukumarappan, Handbook of farm, dairy and food machinery engineering (2nd Edition), M. Kutz, Ed. Academic Press, (2013).

[25] A. Legrand, J.-C. Leuliet, S. Duquesne, R. Kesteloot, P. Winterton & L. Fillaudeau, “Physical, mechanical, thermal, and electrical properties of cooked red beans (Phaseolus vulgaris L.) for continuous ohmic heating process”, J. Food Eng. **81** (2007) 447.