Chapter 5
Design and Development of an Efficient Meat Smoker

Ahmad Qamarul Arifin Rahman and Faiza Mohamed Nasir

5.1 Introduction

Meat smokers are outdoor cooking appliances that can maintain a low cooking temperature for an extended period of time in order to produce smoke and trap heat. For a long time, people have used smoking to preserve and flavour food (Venema 2016; Adeyeye 2019). Before the food spoils, people have discovered that food that has been exposed to smoke lasts longer. Smoking has been around for a long time and is still popular all over the world (Yang and Po-Yuan 2019). This technique has been used in some countries to preserve fish and meat, especially in the fall to ensure a steady supply of protein throughout the winter and to reduce hunting activities.

In Malaysia, meat smokers are used by the hawkers at the night market and operated in an open environment. This exposes the meat to the environmental pollutants such as vehicle smoke, dust, bacteria and virus, raising concerns on the food hygiene. Furthermore, existing meat smokers require complex preparation and require large operating spaces. Existing meat smoker operations, as well as the heat source they impose, must be continuously monitored to avoid overheating, or else the food will be burnt. During the smoking process, the meat should be manually inspected to ensure that the smoking is complete. As a result, this operation necessitates a large number of working hours, making it ineffective in situations where a quick operation is required.

Meat can be cooked in two ways: directly or indirectly. Grilling meat involves using direct heat for a short period of time, whereas smoking involves using indirect

A. Q. A. Rahman · F. Mohamed Nasir (✉)
Universiti Kuala Lumpur Malaysian Spanish Institute, Kulim Hi-Tech Park, 09000 Kulim, Kedah, Malaysia
e-mail: faiza@unikl.edu.my

A. Q. A. Rahman
e-mail: aqamarul@s.unikl.edu.my

A. Ismail et al. (eds.), *Materials and Technologies for Future Advancement*,
Advanced Structured Materials 193,
https://doi.org/10.1007/978-3-031-38993-1_5

heat to cook meat at a low temperature for an extended period of time. Smokers and grills are, in essence, diametrically opposed. The indirect heat of the smoke is what distinguishes it. To put it another way, the meat is not cooked directly over a flame or heat source. Allow the heat and smoke from the fire to permeate the meat instead, keeping it away from flames or direct heat sources. Cooking with indirect heat is simple when one uses a dedicated smoker. Smokers are specifically designed to keep meat away from heat while allowing and absorbing smoke. Smokers are well-designed to allow smoke and heat to circulate freely around the meat to be cooked.

The designs available for smokers are quite limited. This is because most smokers are created by do-it-yourself enthusiasts who love to do it. A small number are used for commercial purposes. In this work, a meat smoker is designed, fabricated, assembled and tested. The meat smoker must be able to produce smoked meat with excellent taste, requires minimal intervention, operates hygienically in a shorter period of time.

5.2 Methodology

5.2.1 Conceptual Designs

Six conceptual designs were developed, after benchmarking with different designs of smokers from do-it-yourself projects. Double barrel or double chamber design were chosen as the main concept as this design would allow better flow of heat and smoke for the meat while minimising the occurrence of burnt meat, compared to single barrel design.

In the double barrel design, there are two barrels or chambers placed on top of one another separated by a channel or connector. The top chamber is used to place the meat (cooking chamber) and the bottom chamber is for charcoal briquettes (Fig. 5.1). There ais the air suction channel and air exhaust channels in the design, where the former is located at the bottom chamber and the latter is located at the top chamber or the cooking chamber.

5.2.2 CFD Simulations

The six conceptual designs of the meat smoker were modelled using the CAD software SOLIDWORKS. CFD simulations for the designs were conducted focusing on the fluid flow and the temperature distribution in the smoker. Results of the CFD simulations provide an initial overview of the effectiveness of the meat smoker without having to produce the actual product.

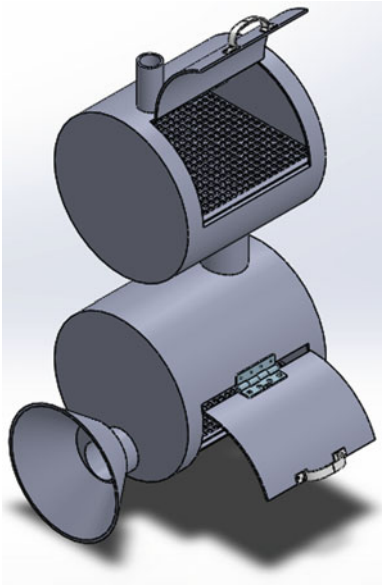


Fig. 5.1 Design concept for the meat smoker

5.2.3 Decision Analysis

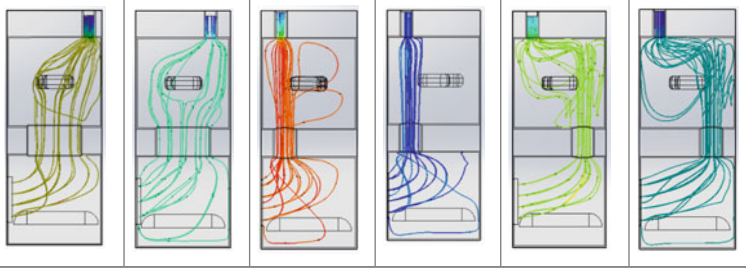
The selection of the final design of the meat smoker is based on the results of the CFD simulations. The results and the designs are illustrated in Table 5.1. Design 5 is the best design based on the results obtained from simulations (Fig. 5.1). It is observed that the temperature obtained at the bottom of the meat and the top of the meat is similar for this design of meat smoker. This allows the meat to be cooked evenly on both sides, top and lower and will not overcook on certain parts.

Once the analysis is done and the design is selected, a fabrication process is performed to test the effectiveness and accuracy of the data that has been obtained through the analysis method.

5.2.4 Fabrication and Assembly

The finished meat smoker is equipped with a temperature reading device in the cooking chamber to make it easier for users to monitor the temperature in the cooking chamber. In addition, it is also equipped with a funnel to direct ambient air by using a fan to ignite the combustion in the combustion chamber and control the temperature in the cooking chamber. The drawings for the final design are shown in Figs. 5.2 and 5.3. The finished meat smoker is shown in Fig. 5.4.

Table 5.1 Results for the CFD simulation

	Design 1	Design 2	Design 3	Design 4	Design 5	Design 6
Shape of chamber	Cylinder	Cuboid	Cylinder	Cuboid	Cylinder	Cuboid
Maximum temperature (K)	508.00	454.77	498.47	571.95	581.49	576.57
Air flow						

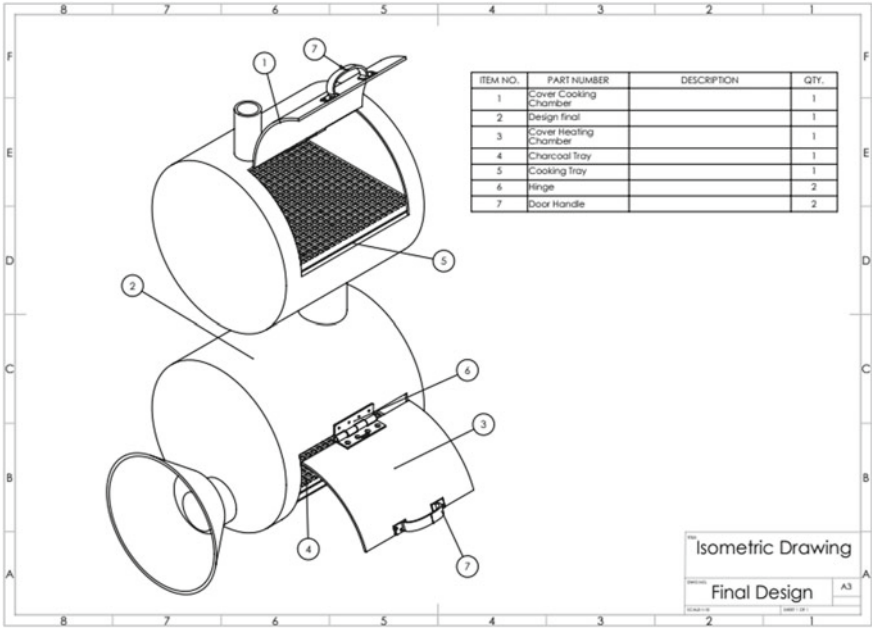


Fig. 5.2 Isometric drawing of the final design

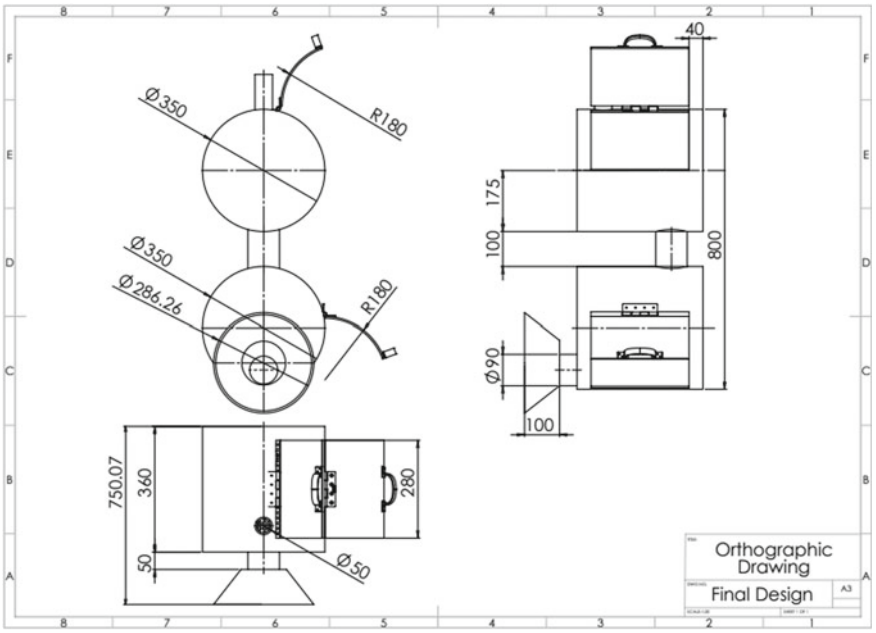


Fig. 5.3 Orthographic drawings of the final design

Fig. 5.4 The finished meat smoker **a** front view with the chamber openings closed, **b** front view with the chamber openings open and **c** side view

5.3 Results and Discussion

Testing of the meat smoker was conducted to ensure that it works as required. The meat smoking process was conducted by using the meat smoker or by using a conventional oven cooker. The meat was prepared and marinated using the same ingredients. Two samples of marinated meat with the same weight of 500 g were prepared and cooked. The time taken for the meat to be cooked was recorded. The conditions of the meat after every 30 min were also observed for both smoking methods.

Results indicate that the meat smoker was able to cook the marinated meat within 1 h and 30 min at a temperature of 225 to 250 °F. Under the same conditions, the oven took 2 h 30 min to 3 h to fully cook the marinated meat. This demonstrated the ability of the meat smoker to cook the meat at half the time required for the oven cooker.

Comparing the appearance of the cooked meat using both cooking methods, it is found that the oven-cooked meat looks a little darker and a little drier than the smoker's meat (Fig. 5.5). The meat cooked using the smoker looks tastier and the outside of the meat looks fresh.

When it comes to cooked meat tenderness, oven-cooked meat does not compare favourably to meat cooked in a smoker (Fig. 5.6). Because oven-cooked meat is drier on the inside, it is not as tender as meat that has been smoked in a smoker. Meat cooked in a smoker is tenderer and juicier than meat cooked in a conventional oven because it is not cooked over an open flame but rather over a smoke fire, thereby cooking it indirectly over an open flame where there is a source of heat.

Fig. 5.5 The appearance of **a** oven-cooked meat, **b** smoked meat

Fig. 5.6 Appearance of sliced meat cooked by **a** oven and **b** the meat smoker

5.4 Conclusion

The aim of this work was to successfully develop an efficient smoker that can reduce the time required to smoke and cook meat, operating with minimal supervision, maintaining high level of food hygiene while maintaining the uniqueness of smoke flavor itself. By employing a design process, a meat smoker was developed, fabricated, assembled and tested. Testing of the smoker indicated that it is capable of cooking the meat at half the time required by a conventional oven, with juicier appearance and tastier.

Acknowledgements We would like to acknowledge the support of UniKL MSI in completing this work successfully within the COVID-19 pandemic.

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