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Design of a Movable Swine Roasting Machine

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ABSTRACT

The objective of this research was to design a transportable swine-roasting machine. The methodology was in two parts. The first was to survey the local knowledge of roast swine and to examine the process. The second was to design a movable swine-roasting machine. The result showed that most manufacturers and distributors produced roast swine. Their daily income was about USD170 per day. The cost of the roast swine was USD5.5 per kilogram. The process involved slaughtering a swine that was approximately 25 kg, removing the offal and inserting lemongrass stalks into the carcass. The pig carcass was then roasted on hot charcoal for about 3 hours and turned by hand. The average chest diameters of 47 roast swine were 0.332, 0.307 and 0.244 m. (large, medium and small, respectively). The design concepts of a movable swine roaster involved equipment that allowed roasting on only two sides of the swine, which was supported by stainless steel pipes (the swine holder) rotated by a 0.5 hp electrical motor. The amount of charcoal for a transportable swine-roasting machine was between 14 and 18 kg depending on the weight of the swine to be roasted. The average temperature of the roaster was 260°C. The average weight of fresh pork to charcoal was around 1.46:1 kg. The roaster was easy to use and maintain.

Keywords: Roast pork, swine-roasting machine, swine, roaster, movable roaster

INTRODUCTION

By 2014, Thailand's swine industry was relatively mature and produced 15.8 million swine or 1.19 million tonnes of pork annually. In addition, the consumption of pork reached 1.18 million tonnes as reported by The Swine Raisers Association of Thailand in 2014. This is equivalent to an average consumption of 17.9 kilograms per person per year. In the same year, Thailand exported 20,000 tonnes of pork and pork products, which were valued at around USD108 millon or 1.67% of total production, and it was projected to increase steadily. Admittedly, a large number of pork

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and pork products were manufactured for domestic consumption. Nakhon Pathom province, recognised as one of Thailand's top swine-producing provinces, experienced an oversupply of piglets in 2007. Local food consumption would have had a significant relationship within the context of daily living, thus reflecting the availability of natural resources and the development of local knowledge (Anantathanachai, 2010). Similarly, people in Tha Kham, Sam Phran and Nakhon Prathom provinces considered swine their most important resource. Relying on local wisdom, they successfully developed a delicious dish known as roast swine, which had a unique taste and quality as it was the result of using academic principles of food production. The traditional method of roasting swine was to cook the meat on the ground, which ran the risk of producing low-quality meat (Wessapan & Borirak, 2014).

Traditional meat products are developed using different processes. The success of such products can be seen at different levels (Chu-iad, 2008). Certainly, government agencies and local authorities are required to play a vital role in developing human resources in the industry while providing them with greater knowledge of operating and managing all aspects of the business. In addition, the production of roast swine was only appropriate for day-to-day selling (Kitthawee et al., 2013). Given that the majority of customers preferred fresh roast swine, the product was not meant to be kept overnight. Transportation and selling period became key factors in roast swine production. If transportation took more than 1 hr, the roast swine would be considered inferior in quality and thus, become less appealing. A swine-roasting machine was therefore developed to cook small pieces of meat (Teeboonma et al., 2006; Paengteeresukkamai, 2011; Wessapan & Borirak, 2014).

As the researcher had foreseen the significance and possible impact of the design of the mobile swine roaster on the roast swine industry, it was necessary to conduct a preliminary survey and gather vital information about the product. The aim of this research was to design a portable swine roaster to facilitate roasting at selling locations.

MATERIALS AND METHOD

Fundamental Information

The researcher conducted a preliminary survey on traditional roast swine at local markets and manufacturing venues with the assistance of the Tha Kham Subdistrict Administrative Organisation in Nakhon Pathom's Sam Phran district. The survey covered several topics including the production process, the preparation of raw materials and ingredients, the measurement of swine of different sizes prior to roasting and the determination of charcoal temperature at four positions in the roaster as well as swine temperature at two positions on the swine holder every 15 min for 3 hrs. The temperature was measured using an IR thermometer, CEM DT-8835.

Design Principles

The portable swine roaster was designed using principles similar to the traditional large roaster traditionally placed on the ground, as shown in Figure 1. Judging from the description in Figure

2, only the sides of the swine are exposed to heat using this method. Moreover, the fat does not drip directly onto the hot charcoal (Wessapan & Borirak, 2014). The swine is positioned to be turned slowly to receive heat from the burning charcoal (see the two arrows in Figure 2). However, heated charcoal is required at the lower middle part of the roaster. The other remaining sides of the swine are exposed to the heat acquired from the same position of the heated charcoal in the next round. As the heat is maintained at the same temperature, the whole body of the swine is roasted twice in one rotation.

The portable swine roaster is designed to maintain the heat from both sides, which can be controlled manually. The roaster is made of a steel sheet and other inexpensive materials chosen for their portability and heat-resistant properties. The portable swine roaster consists of a 9.5 mm (3/8 in) metal sheet designed in half cylinder, a metal roast set, a worm-gear speed reducer (40:1) powered by a simple pulley and belt system and a 0.5 hp electric motor that powers the continuous turning throughout the roasting period as shown in Figure 4.

Figure 1. Traditional roast-swine manufacturing

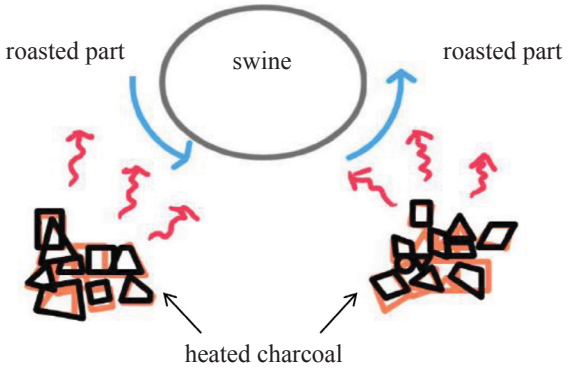
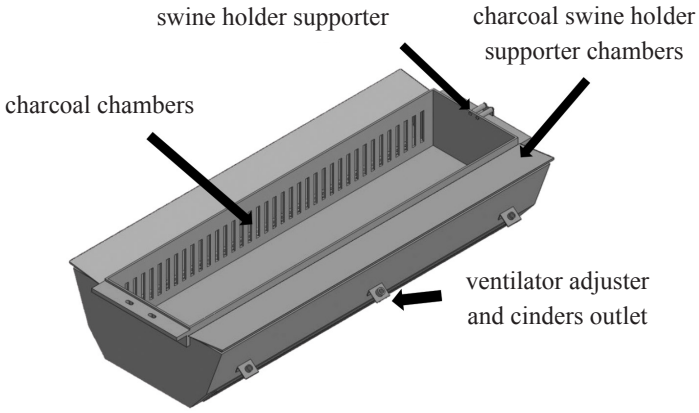
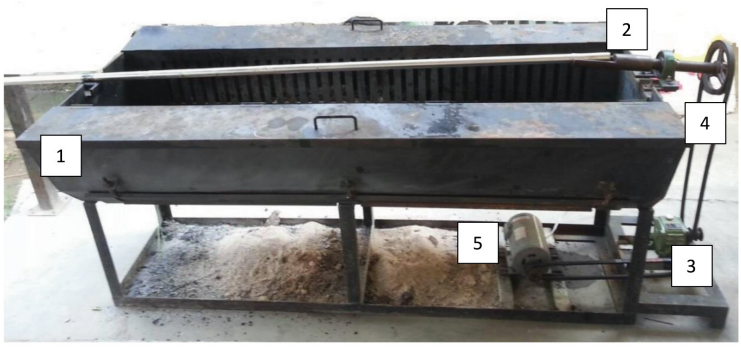


Figure 2. Concept of heat transfer from burning charcoal to swine

Figure 3. Roasting of swine by local manufacturer





1=metal sheet; 2= metal roaster set; 3=a worm gear; 4=belt system; 5=electric motor

Figure 4. Portable swine roaster

RESULTS AND DISCUSSION

The taste of the roast swine was similar to that of Trang-style roast pork, but the former had a richer herbal fragrance and a crispy skin commonly eaten with spicy sauce.

General Information

According to a survey conducted with eight families in Tha Kham, Sam Phran and Nakhon Prathom provinces, the families were able to earn up to USD170 daily from sale of roast swince. A selling place should be set up somewhere in the local market less than 30 km away from the manufacturing site. The retail-selling price of roast swine is around USD5.5 per kilogram, where 15 kg could be the weight of the swine after the roasting process. The average weight of the unprocessed swine is 25 kg and its cost is around USD37 per unit, as shown in Table 1.

Table 1
General Information About Roast-Swine Manufacturers

Specific Information	Average Value
Average income per family (USD)	170
Recommended daily selling period (hr)	6
Retail selling price per kilogram (USD)	5.5
Net weight after the roasting process (kg)	15
Net weight before the roasting process (kg)	25
Cost per unit (USD)	37

The manufacturing process takes about 3 to 4 hrs for each swine. The wine for slaughter should weigh around 20 to 25 kg. The swine's belly must be cut to remove its entrails. The belly is then filled with several types of herb such as lemongrass, kaffir lime leaves and banana leaves to replace the entrails that were removed. A swine holder, consisting of a long iron pipe is used to hold the swine longitudinally as it is roasted, as show in Figure 3. It is necessary that the swine be firmly placed on the iron pipe over the heated charcoal, which should not contain red flames that could cause the swine's skin to get burnt. Finally, while roasting, the operator must repeatedly turn the swine slowly to ensure that it is evenly and thoroughly cooked. A few drops of orange food colouring can be applied on the swine's skin to enhance the appearance of the product.

For this study, it was necessary to measure the size of 47 live swine with a focus on nose-to-tail length as well as pectoral and pelvic diameters (shown in Table 2). Swine of different sizes were categorised by the manufacturers.

Table 2
Sizes of Swine Prior to Roasting

Size (m)	Length (m)	Chest Diameter (m)	Hip Diameter (m)
Small	0.945	0.244	0.273
	(0.780)*	(0.029)	(0.045)
Medium	1.090	0.307	0.351
	(0.680)	(0.021)	(0.026)
Large	1.184	0.332	0.389
	(0.120)	(0.023)	(0.034)

*Standard deviation of size

The researcher also measured the temperature of the heated charcoal at four positions: the front, back, left and right as well as the temperature of the roasting swine every 15 min for 3 hrs (shown in Table 3).

Table 3
Temperatures of Swine and Heated Charcoal Throughout the Roasting Period

Sample	Temperature (°C)											
	Min 15	Min 30	Min 45	Min 60	Min 75	Min 90	Min 105	Min 120	Min 135	Min 150	Min 165	Min 180
Swine	33.8	70.0	127.5	149.1	161.3	164.7	168.7	167.8	169.7	162.4	158.0	156.1
	(3.9)*	(28.7)	(18.1)	(20.2)	(10.1)	(16.0)	(13.3)	(19.0)	(17.4)	(22.3)	(24.7)	(32.7)
Charcoal	45.5	57.3	66.3	85.0	376.5	611.8	652.5	681.0	695.5	679.6	657.8	643.4
	(5.5)	(3.3)	(5.5)	(17.7)	(39.1)	(69.1)	(70.5)	(72.8)	(79.8)	(68.6)	(61.6)	(31.9)

*Standard deviation of temperatures

Roast-Swine Machine

The portable swine roaster consisted of a 9.5 mm (3/8 in.) metal sheet shaped into a half cylinder and a metal roasting set (Figure 4). The metal roasting set was able to support a 12.7-mm (1/2 in) stainless steel pipe with a length of 2 m and a 1.60×0.50×0.50 m^3 roast. The roaster's height was 0.7 m above the ground and it was more convenient to operate than a traditional roaster. It also featured a worm-gear speed reducer (40:1) powered by a simple pulley-and-belt system as well as a 0.5 hp electric motor and two charcoal chambers installed on the front of the roaster. There were two ventilator adjusters and cinder outlets at the bottom of the charcoal chambers. Rollers were installed at both ends of the roaster to support the swine holder to ensure that the stainless steel pipe was rotating slowly throughout the roasting period.

The research continued with the roasting of three uncut swine with individual weights of no more than 40 kg as shown in Figure 5. The charcoal was heated in the charcoal chambers before the swine was firmly placed on the stainless steel pipe of the swine holder, where the

12.7-mm (1/2 in.) roller was installed on one side of the roaster. With the assistance of the 0.5 hp electric motor, no fat dropped on the heated charcoal or the smoke along the roasting platform.

Figure 4 shows the appropriate temperatures for different types of meat. Generally, pork requires up to 85°C for thorough cooking. According to the roasting results, the temperature of the swine meat (T_m), the swine skin (T_s) and the roaster (T_o) should increase consistently with the roasting time as it increases. For the swine, the temperature should increase heavily during the first roasting hour and drop after 2.5 hrs. The temperature seemed to stabilise after 2.5 hrs of roasting. Figure 7 records a high temperature of 100°C and 74°C for the swine skin and the swine meat, respectively. It took about 3.5 hrs to achieve equal temperature for the swine meat and the swine skin, while the temperature of the roaster was estimated to rise by three times higher than the temperature of the swine skin. This characteristic temperature is normal for a meat roaster (Teeboonma et al., 2006). However, at least 2 hrs is required to cook the swine thoroughly, as the meat can only maintain temperatures of up to 70°C. The movable roaster machine has the same the characteristic temperature as a traditional roaster, and this ensures that the crispiness and taste of the swine are similar. Fortunately, the manufacturer cooked the swine at a local market using the movable roaster machine.

Based on Table 4, 4.5 hrs were needed to roast the swine thoroughly using the movable roasting machine, during which the amount of charcoal required ranged from 14-18 kg., depending on the weight of the swine being roasted. In other words, 1 kg of charcoal was required to roast 1.46 kg of fresh swine to produce a roast of equal characteristics as traditional roast swine.

The advantages of using this roasting machine were that it allowed for a higher height, which is ergonomically better than the position required for the traditional method; a uniform roast was possible because of the continuous turning during roasting, and; the process was more hygienic as it avoided ash and dust from the burning charcoal.

The portable swine-roasting machine was delivered to manufacturers for their use, and many were satisfied with its easy-to-use operation. However, the roaster needs further development in terms of weight and heat delivery, for which a shorter roasting period and greater awareness of skin burning are also needed.

Figure 5. Roasting of swine

Figure 6. Levels of temperature suitable for cooking different types of meat

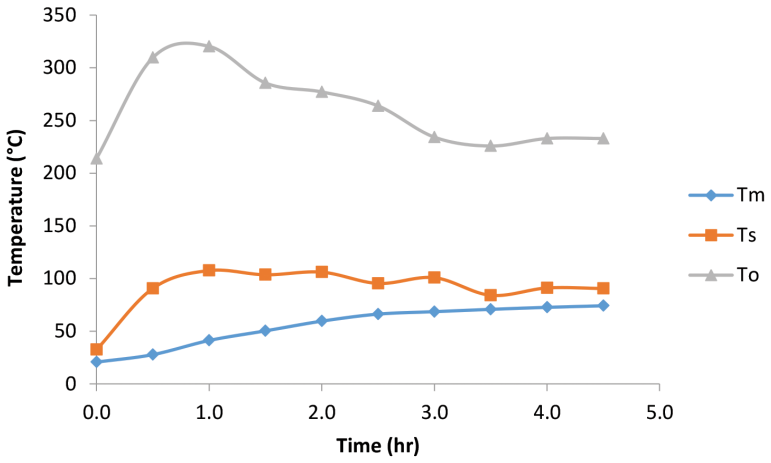


Figure 7. Relative temperature of swine meat (T_m), swine skin (T_s) and roaster (T_o)

Table 4
Results of Roast Swine on Machine

No.	Weight (kg)			Roasting period (hr.)	Amount of charcoal (kg)	Average temperature of roaster (°C)	Average temperature of swine (°C)	Fresh meat weight to charcoal* (kg:kg)
	Live swine	Before roasting	After roasting					
1	35.00	25.00	15.10	4.50	18.00	319.22	75.67	1.39
2	25.00	22.00	16.00	4.50	17.00	257.44	80.10	1.29
3	28.00	24.00	19.00	4.50	14.00	203.07	70.67	1.71
Average	29.33	23.67	16.70	4.50	16.33	259.91	75.48	1.46

*Weight ratio of fresh meat and required charcoal to cook the meat (kg:kg)

CONCLUSION

The goal of this research was to promote the invention of a movable swine machine developed to facilitate roasting at selling locations. According to a survey conducted among manufacturers and distributors of roast swine, they are able to earn up to USD170 in daily income from the sale of the meat. The average amount of roast swine is expected to be sold on a daily basis, where the retail-selling price is USD5.5 per kilogram. The process of manufacturing each roast swine takes about 3 to 4 hrs. First, a live swine weighing around 20 to 25 kg is slaughtered. Then its entrails are removed and replaced with several types of herb. Then the manufacturer uses a swine holder, which is a long iron pipe used for roasting swine that is slowly and repeatedly turned by hand. The swine is divided into three major size categories, including small (0.945 m, 0.244 m and 0.273 m), medium (1.090 m, 0.307 m and 0.351 m) and large (1.184 m, 0.332 m and 0.390 m). The average temperature of heated charcoal and the swine meat is 437°C and 135.5°C, respectively. The portable swine roaster is powered by a simple pulley-and-belt system and is powered by a 0.5 hp electric motor, and its metal roast set possesses a bearing to support a 12.7-mm (1/2 in.) stainless steel pipe with a length of 2 m and a $1.60 \times 0.50 \times 0.50$ m^3 roast. The amount of charcoal needed is 14 to 18 kg depending on the weight of the swine to be roasted, and the average temperature of the roaster is 260°C. The average weight ratio of the fresh pork and charcoal to cook the meat is around 1.46:1 kg. The roasted swine made with the movable roaster is the same as swine cooked with a traditional roaster that has less manpower and product mobility, thus making the roast swine more accessible to the public.

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