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USING THERMAL IMAGES TO MONITOR TEMPERATURE STABILITY IN SALMON SMOKING ROOM

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Abstract

The cold smoking process in a commercial smoke house was used for Salmon fillets were dried for 12 hours at a temperature of about 23°C. It was cold smoked for 12 hours using wood chips. The dry matter and salt content were generally determined. Samples were cooled on slides at 5°C for 6 hours before vacuum packing and then cold stored at approximately 4°C. While inside the freezing room, before smoking the fish sample which ranged from -17.5 to -18 °C. The characterize temperatures of fish smoking house and infrared imagingwith thermal analysis has been used to monitor temperature distribution in those ovens, compare heat transfer and energy efficiency across different ovens, and understand the overall performance of the house, including heating and heating rate. The results recorded the average temperature inside the smoking room, which ranged from 21.34 to 23.34 °C, the temperature stability relies inside the cooling room when the temperature differences between 0 and 1 °C on three dimensions inside the cooling room.

Key words: *cold, smoking, salmon, temperature, infrared thermography*

INTRODUCTION

Smoking is one of the oldest and most widespread post-harvest processing techniques, particularly because it can add value to fish. The World Health Organization (WHO) and the Food and Agriculture Organization (FAO) define fish smoking as the practice of preserving fish or other foods by exposing them to smoke from burning wood or plant material [15].

During produce smoking salmon, the waste was recorded about 20% (skin, viscera, backbone frames and cuts off) of the total mass from salmon slices. Also extract fish oil from this waste by using cold pressing and wet rendering methods provided with 18% of oil productivity[7].

There are multiple subprocesses involved in this process, including as cleaning, drying, heating, fermentation, and smoking. There are four different ways to smoke fish: liquid, hot, cold, or electrostatic. In addition to enhancing the fish's flavor, color, and odor, smoking primarily extends its commercial life [8].

The most widely used and traditional way of processing fish is fish smoking. Fish is an important component of a balanced diet and gives humans the protein they need to rebuild tissues and repair their bodies. Hundreds of people are employed by the fish smoking industry, which also acts as a link to other companies in the fish industry (fish traders, fish smokers, smoked fish merchants, etc.). Because the smoked fish industry has large marginal economic returns, it is tremendously profitable [6].

According to the results of the fuel used in the processing (smoking) of the fish in the earlier experiments, 68 (44.16 %) and 86 (55.84 %) smoked fish using charcoal. implying that the majority of smokers and fish processors utilize firewood for fish processing and smoking [5].

Food preservation and processing through smoking and smoke drying are among the most ancient and customary methods employed by humans for over ten millennia. In rural areas, the smoke-drying method is frequently applied to vegetables like breadfruit (Artocarpusnobilis) and jackfruit (ArtocarpusheierophylIus), as well as to meat and fish. Smoking is accomplished by exposing food to smoke directly, Hang it above a fire source, such as burning wood, or place it on a wooden rack above your

kitchen.The technology is really basic, and it is being used today [9].

Protein and nutrition are vital to human and national health. Fish are known for their high content of polyunsaturated fatty acids, minerals such as calcium, phosphorus, salt, potassium and magnesium, and vitamins B and D. They are also considered nutritious, rich in protein, and relatively low in fat, saturated fat and cholesterol. Fish decompose rapidly after death due to a number of physical, chemical and microbiological processes.However, several tactics have been tried to delay spoiling as long as possible due to the rising demand for premium fish products [2].

Fish can be smoked in a number of ways, but the two most common ones are hot and cold smoking. This method of smoking can occasionally be separated into three categories: semi-warm smoking (30–40 °C), hot smoking (70–90 °C), and cold smoking (18–25 °C). But other methods are also employed, like liquid smoke condensate and electrostatic smoking. The product is exposed to at least 80 °C and frequently up to 100 °C when hot smoking. The primary goal of cold smoking, which often involves keeping the product's temperature below 30 °C, is to give it a flavor that consumers will find appealing rather than preserve it [12].

An ancient technique for preserving fish is smoking it. This procedure extends the fish's shelf life while enhancing its flavor, color, and texture. It does this by combining the benefits of an initial salting with the antibacterial properties of certain smoke constituents (phenols, carboxylic acids, and formaldehyde). Because smoked salmon costs far more than fresh or frozen salmon, it is seen as a luxury good [16].

Smoking can be done cold, hot, or liquid. All of these methods provide high-quality items that are well-liked by customers. Cold smoking is most frequently employed in conjunction with dry-salting and is typically carried out at temperatures between 20 and 30 °C for two to twelve hours at a humidity rate of 60 to 75%. For two to four hours, hot smoking is done at temperatures exceeding 60 °C (often between 100 and 120 °C). Smouldering sawdust or shavings of a certain type of wood (beech, hickory, or oak) in the oven just below the fish that is suspended produces the smoke in both methods. Additionally, given regulated temperature and spring conditions, smoke from external smoke generators might be fed to the smoking chamber [4].

Heat is transferred from one thing to another through radiation, a type of infrared radiation, without any physical touch. The measurement of surface temperature can provide information about the physical and health status of humans and other living things. Skin emissivity plays a significant role in identifying the genuine skin temperature [1].

Since many factors may affect thermal imaging, when working at a particular observation scale, it is critical to assess how the measurement environment will probably affect the data to be extracted from the image. Similar to traditional imaging cameras, thermal imaging cameras are constructed using a lens that directs infrared light onto a detector. There are three sources of radiation that hit a thermal camera. Both radiation from the target item, Wobj, and radiation from its surrounds, Wamb, which has been reflected onto the object's surface, are detected by the camera [3].

The invisible radiation patterns of objects are transformed into visual images in thermal remote sensing, It is called a thermogram or thermal image. Thermal sensors combined with optical equipment mounted on aircraft or satellites can be used to obtain thermal images. This technology can be applied in a variety of industries where heat is generated or lost in space and time since it is a non-invasive, non-contact, and non-destructive method for determining the thermal qualities and features of any object of interest [13].

One non-destructive testing method for figuring out an object's surface temperature is infrared thermal imaging. The use of this technology in animal husbandry, namely in the production of chickens, pigs, and dairy products, is growing. Evaluation of sickness, edema, and stress in animals has been aided by the technique, which can distinguish variations in peripheral blood flow from

variations in heat loss. additionally identify heat stress in plants [10].

One non-destructive testing technique that can be used to measure an object's surface temperature is infrared thermography (IRT). The surface-emitted infrared radiation is captured by thermal cameras, which then translate it into electrical impulses to produce a thermal image that displays the distribution of surface temperature of an object. Each shade in this technique represents a specific temperature range associated with a given scale [11].

At temperatures higher than absolute zero, the mobility of atoms and molecules on an object's surface releases energy known as infrared radiation. The temperature of the material affects the emittance's strength. Stated differently, the intensity of infrared energy produced increases with temperature. In addition to emitting infrared radiation, materials can also reflect, absorb, and, in certain cases, transfer this energy. The amount of thermal radiation absorbed by the object equals the amount radiated by it when the temperature of the material is equal to that of its surroundings [14].

The main objectives of this study using infrared image to monitor temperatures distribution in fish smoking ovensto optimize the performance of the ovens.

MATERIALS AND METHODS

The experiment was implemented during the year 2024 in one of the fish smoking factories in 10th of Ramadan City, Sharkia Governorate, Egypt. To analyze the thermal performance of fish smoking ovens using thermal imaging. And study the effect of infrared radiation on the performance of ovens. The process of smoking fish includes several stages: 1) Preparation: which includes cleaning the fish and removing the guts. This stage may take a few hours. 2) salting: The salt was covered fish with soaked in a brine solution for phases extending from a few hours to a complete day to add flavor and help in the preservation process. 3) drying: The fish is dried to get rid of excess moisture. This stage take from a few hours to a full day. 4) cold smoking: Salmon is smoked at low temperatures 20-30°C for a period of time ranging from 12 hours to 24 hours or sometimes longer to achieve a mild flavor and moist texture. Finally, 5) packaging: The fish waspacked and wrapped after smoking, and this process may also take a few hours.

Fig 1 shows the smoking oven with dimensions of length 1.90 m, width 2.15 m, and height 2.80 m and Fig 2 shows the distribution of temperatures over Fish smoking oven.

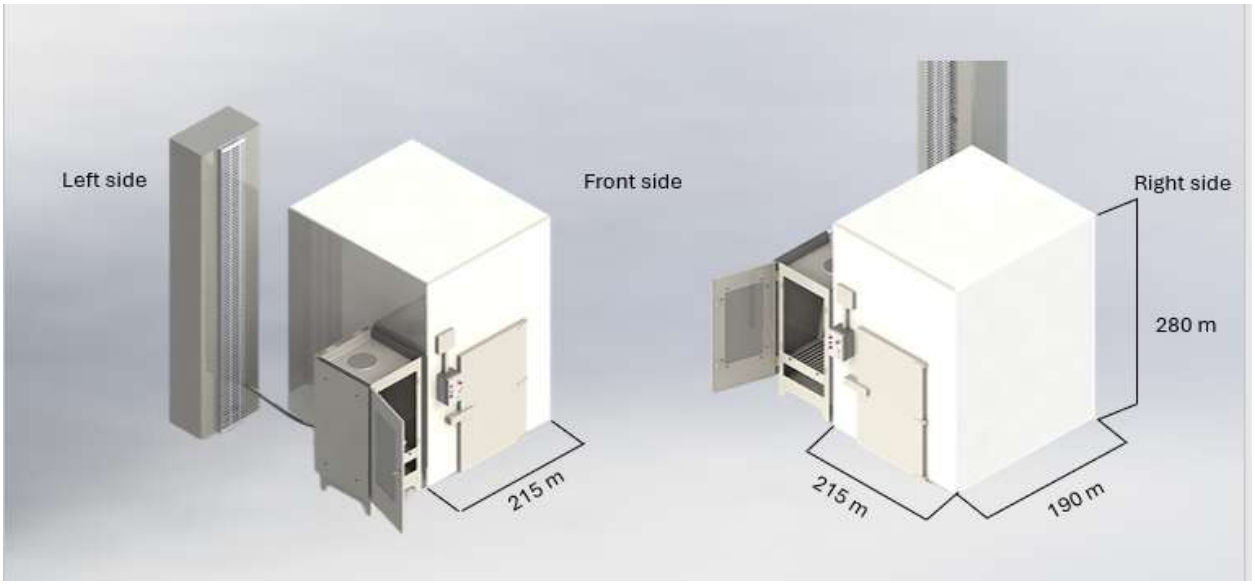

Fig. 1. Fish smoking oven
Source: Author's determination.

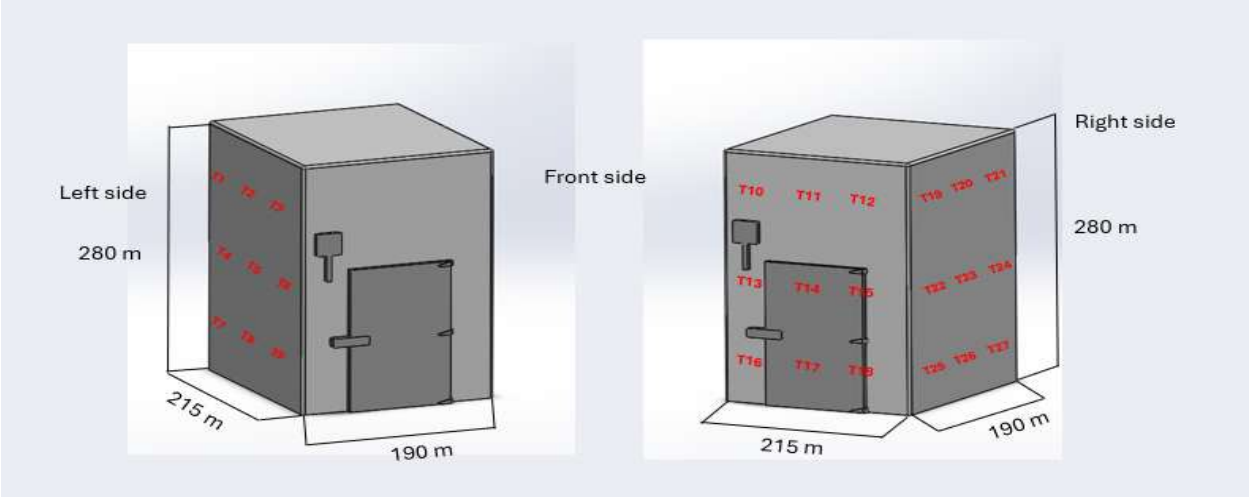

Fig. 2. Distribution of temperatures over Fish smoking oven
Source: Author's determination.

The Thermal camera

With testo Super Resolution technology, the image quality is (320 × 240) pixels with an infrared resolution of (160 x 120) pixels. Features include free analytical software for expert report preparation, automatic hot and cold spot detection, and thermal sensitivity of 0.1 °C. Accurate measurement within ±2 °C and fast with a fixed focus

IRSoft · PC-Software

The IRSoft software was used to process, analyse, and store the images were taken by the testo thermal imager. In addition, integrated reporting was used to provide data in a comprehensible way. The attached thermal imager's parameters can be changed via the instrument control.

MATLAP PC-Software

The Image Analysis system was utilized with the MATLAP program. Samples were taken with digital cameras, and the data was transferred and saved on a PC using a capture card. The MATLAP software was used to analyze the Skillets' pictures. To obtain color indices, three bands—RGB—were obtained for each image.

RESULTS AND DISCUSSIONS

Figures 3 to 7 are shown using MATLAB, where 3D images were extracted from thermal images to measure the effect of temperature on all stages of the fish smoking process.

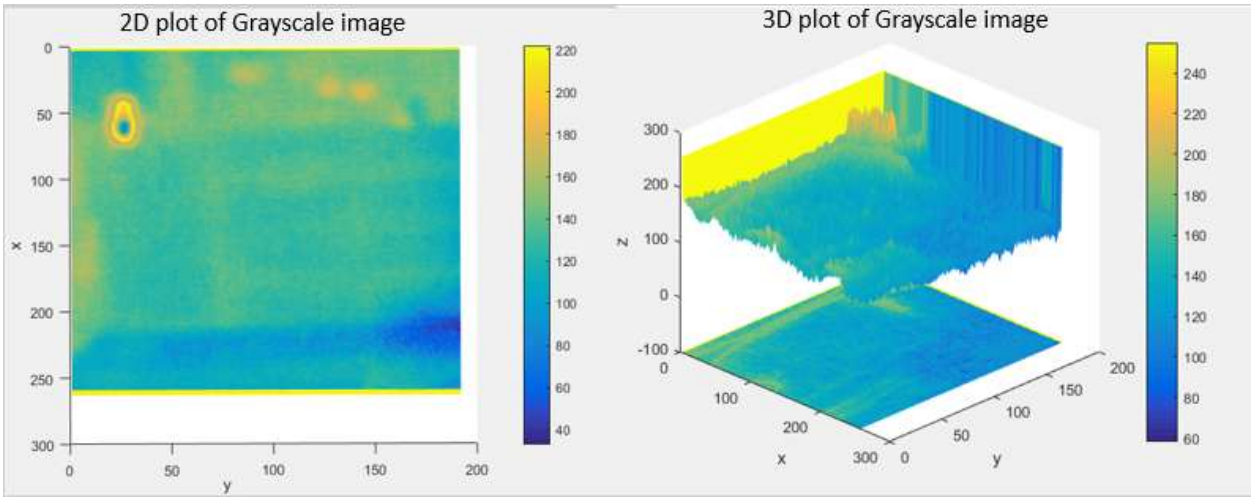

Fig. 3. The profiles of 2D and 3D thermal images for the Smoking-room temperature
Source: Author's determination.

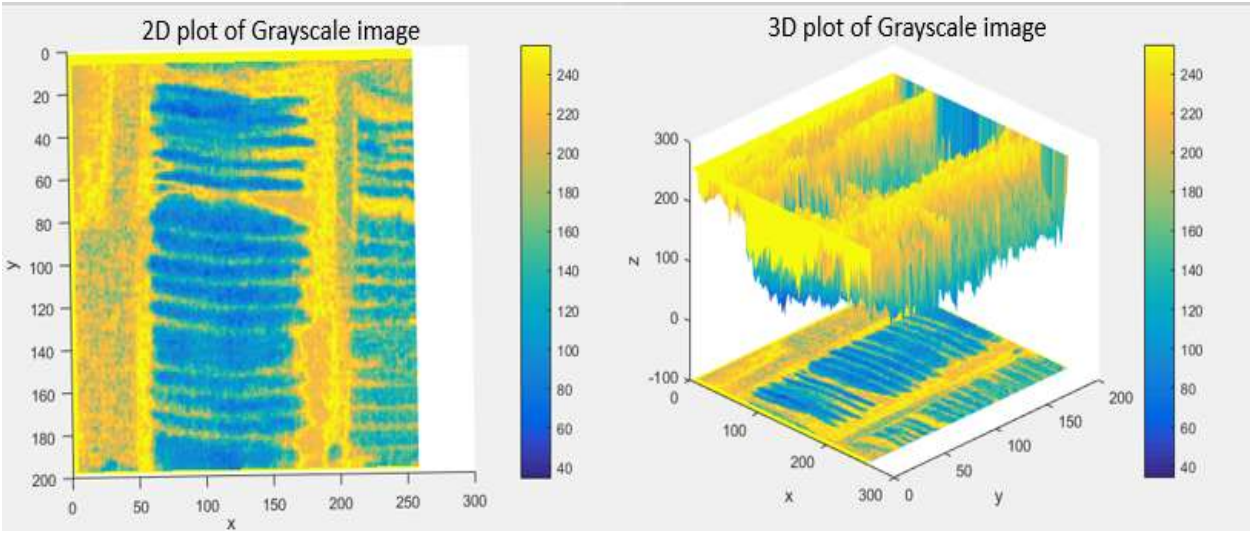

Fig. 4. The profiles of 2D and 3D thermal images for the Salmon slices inside the smoking room
Source: Author's determination.

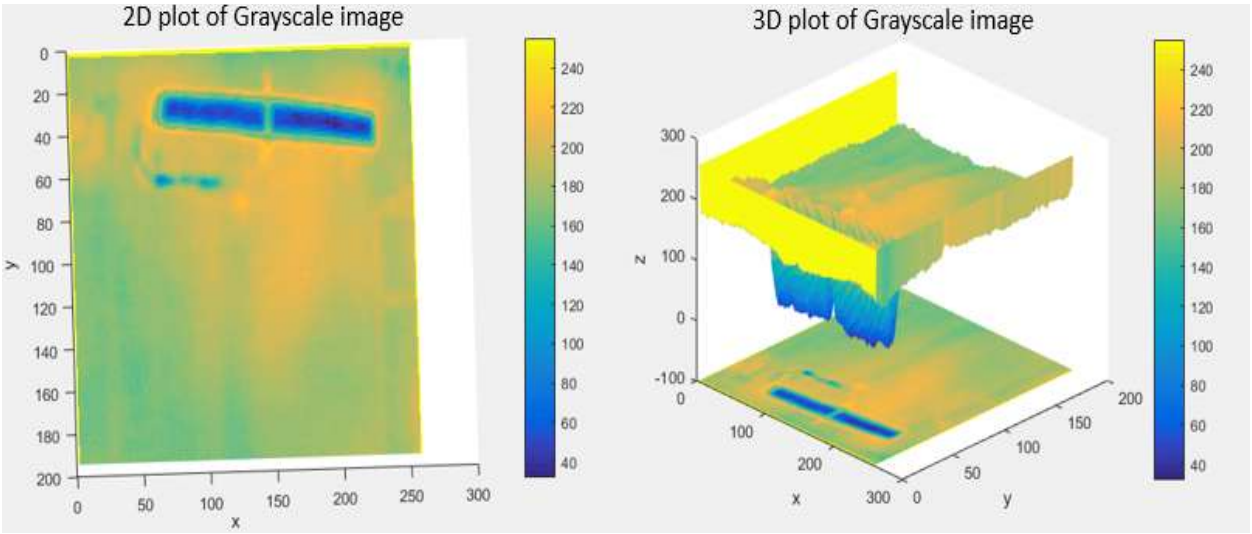

Fig. 5. The profiles of 2D and 3D thermal images for thecooling room.
Source: Author's determination.

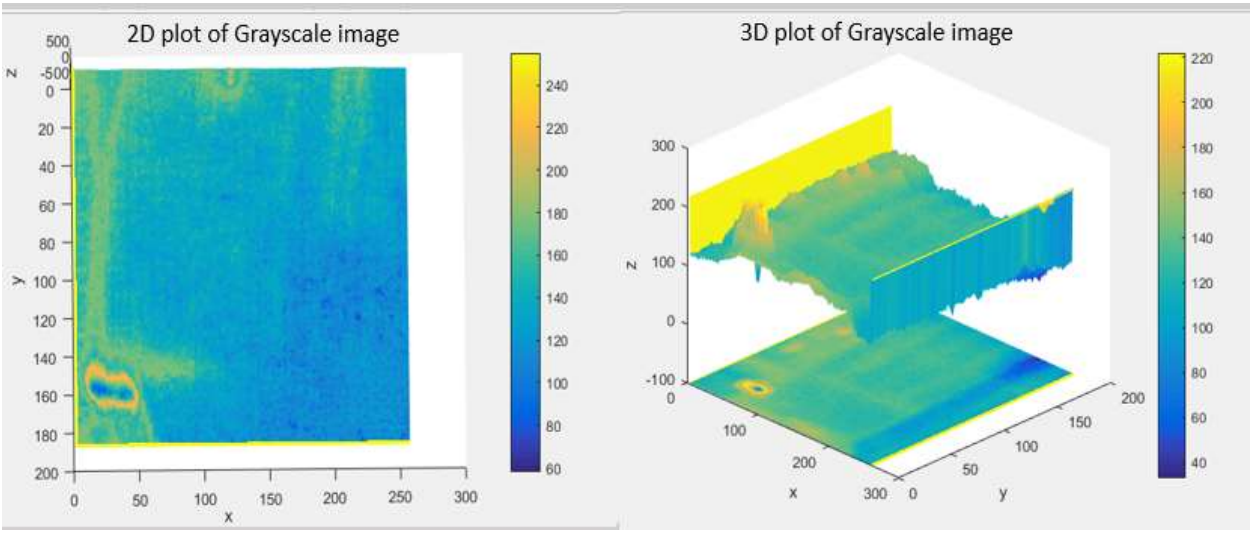

Fig. 6. The profiles of 2D and 3D thermal images for the Freezer room.
Source: Author's determination.

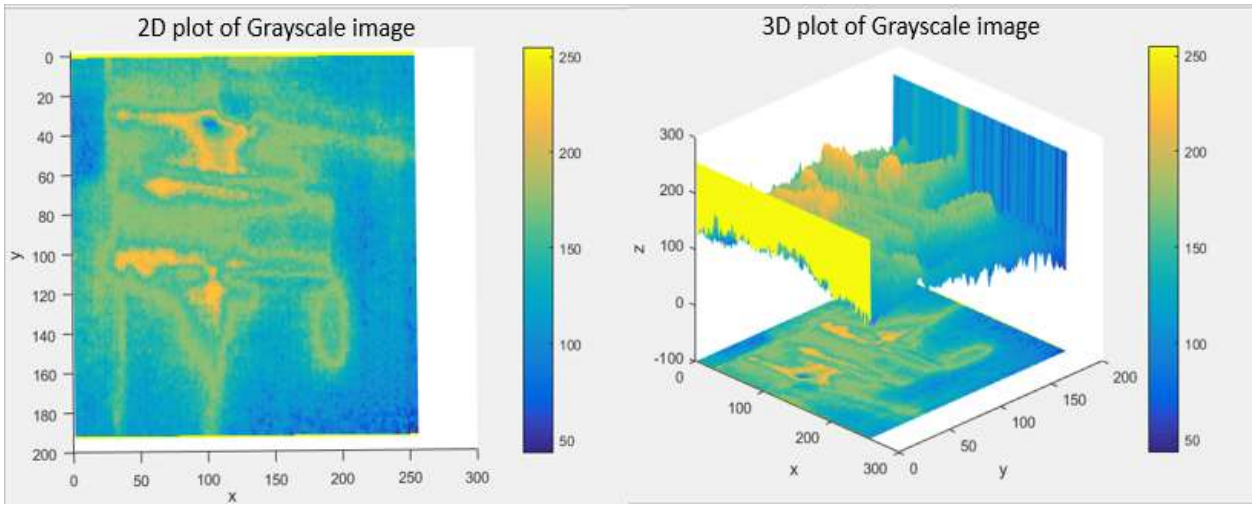

Fig. 7. The profiles of 2D and 3D thermal images for the Frozen salmon fillets inside the freezer room
Source: Author's determination.

Using infrared image to measure the internal temperature of the fish smoking ovens, Salmon slices inside the smoking room in Figures 8, 9, 10, and 11.

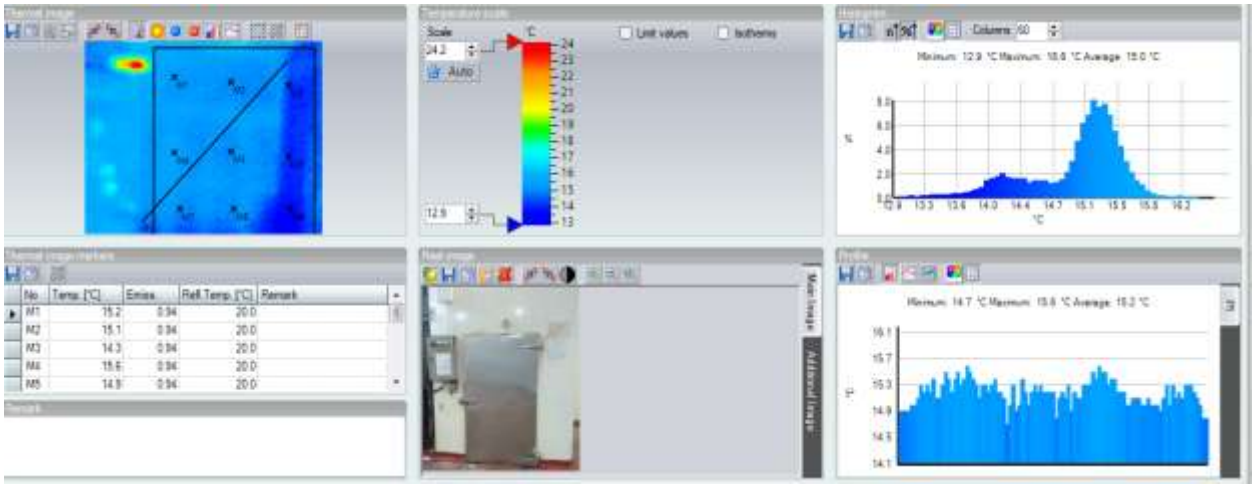

Fig. 8. The internal temperature distribution histogram of the Smoking-room by IRSoft software
Source: Author's determination.

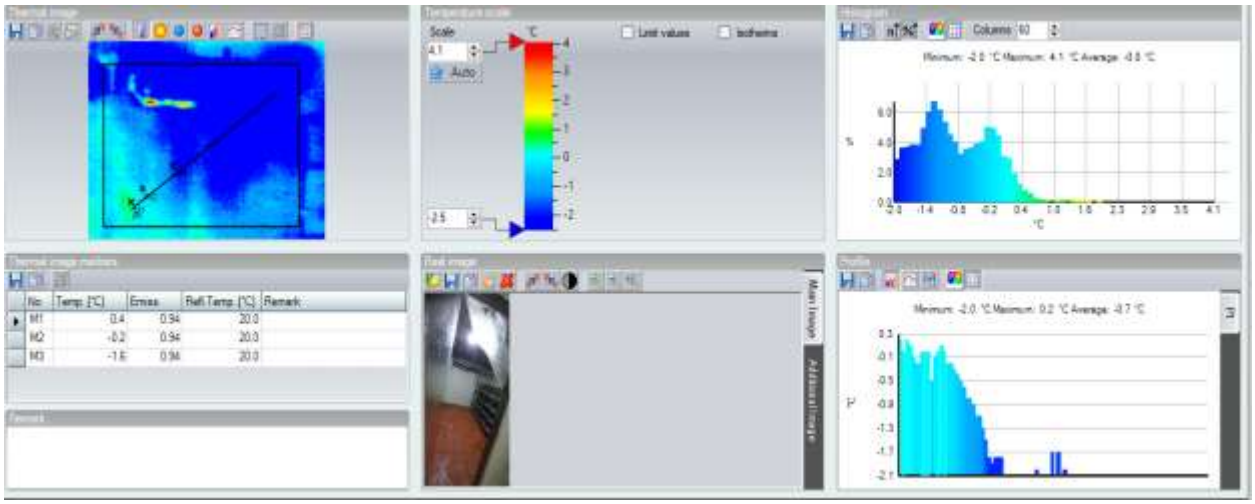

Fig. 9. The internal temperature distribution histogram of the cooling -room by IRSoft software
Source: Author's determination.

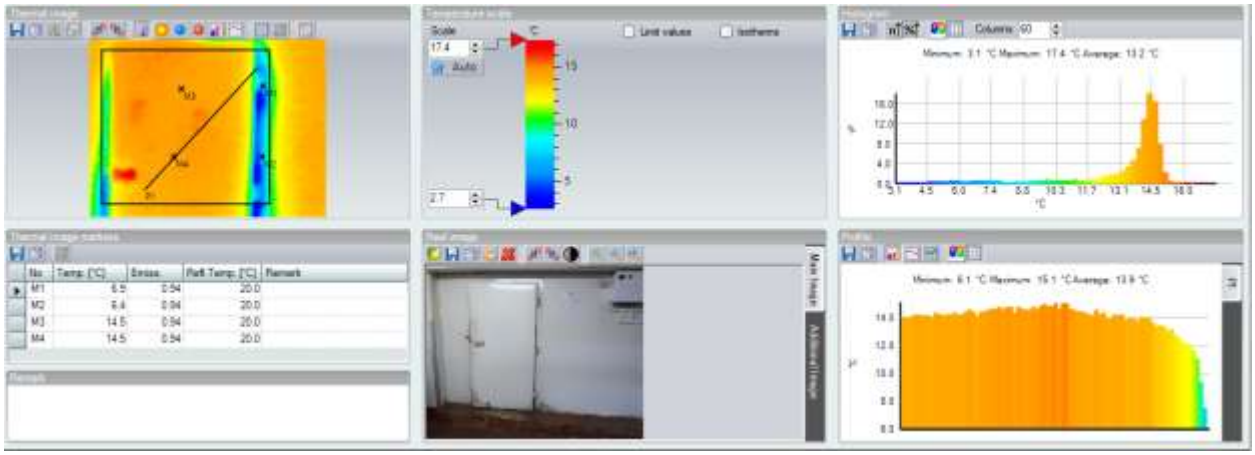

Fig. 10. The internal temperature distribution histogram of the Freezer room by IRSoft software
Source: Author's determination.

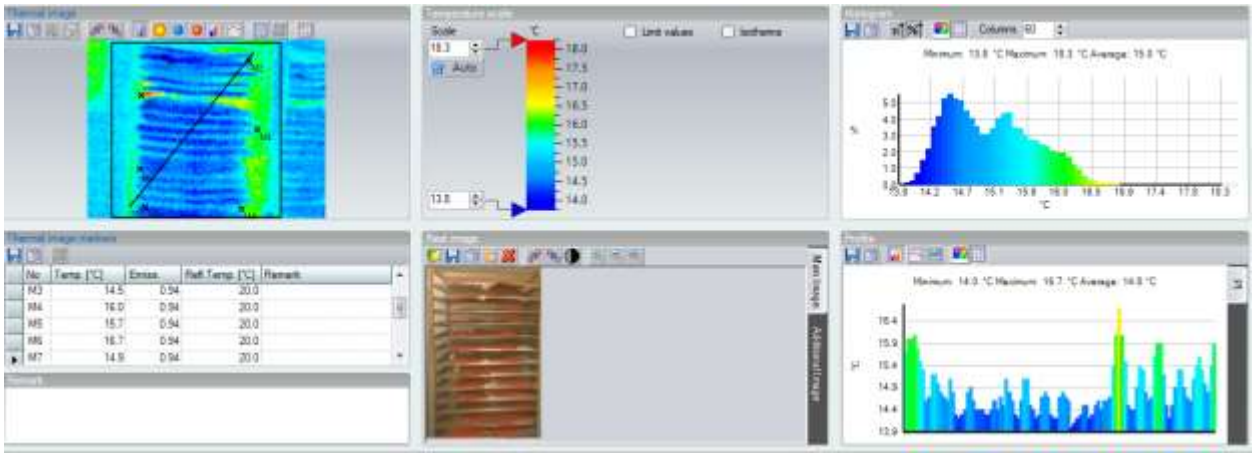

Fig. 11. The internal temperature distribution histogram of the Salmon slices inside the smoking room by IRSoft software
Source: Author's determination.

Figure 12 shows the average temperature inside the smoking room, which ranged from 21.34 to 23.34 ºC during the duration of cold smoking of salmon fillets (12 hours).
Figure 13 shows the average temperature inside the cooling room, which ranged between 0 and 1 ºC during the refrigeration period for the salmon fillets (12 hours).
Figure 14 shows the average temperature inside the freezing room, which ranged between -17.5 to -18 ºC during the freezing period for salmon fillets (12 hours).

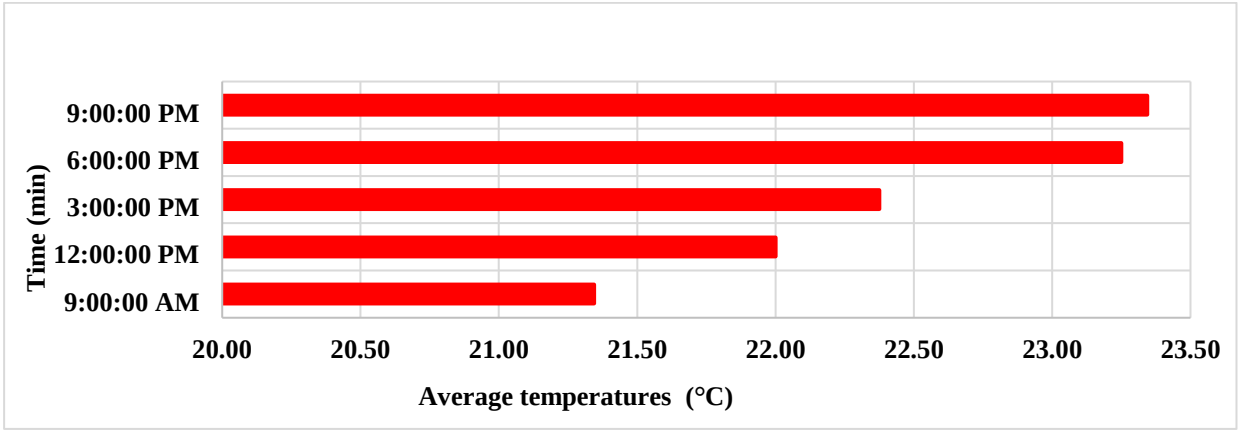

Fig. 12. The relationship between temperature and time in smoking room
Source: Author's determination.

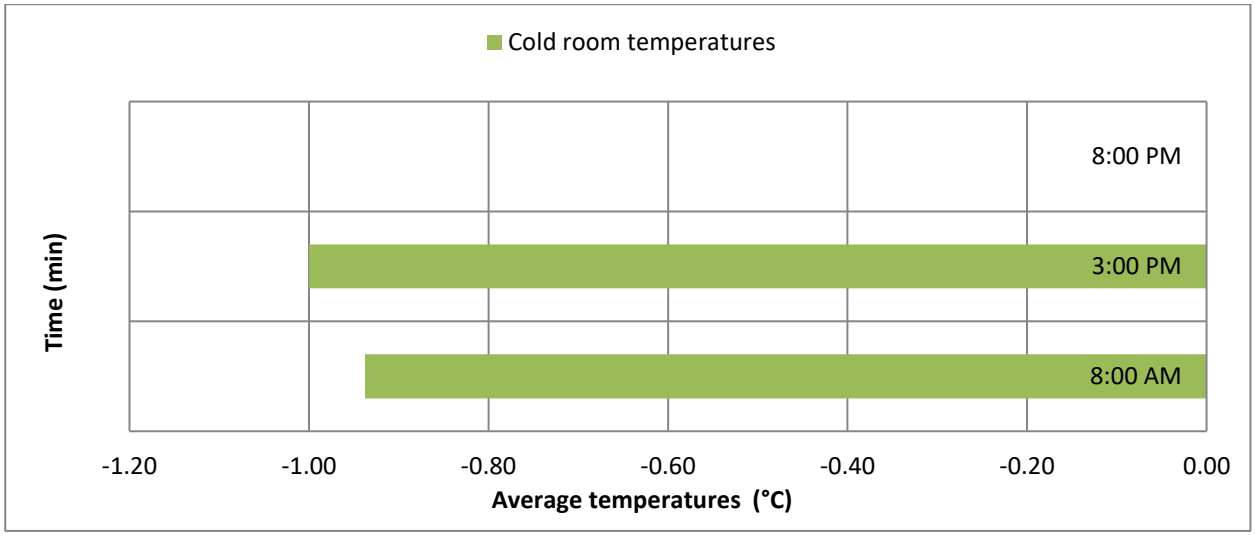

Fig. 13. The relationship between temperature and time in freezer room
Source: Author's determination.

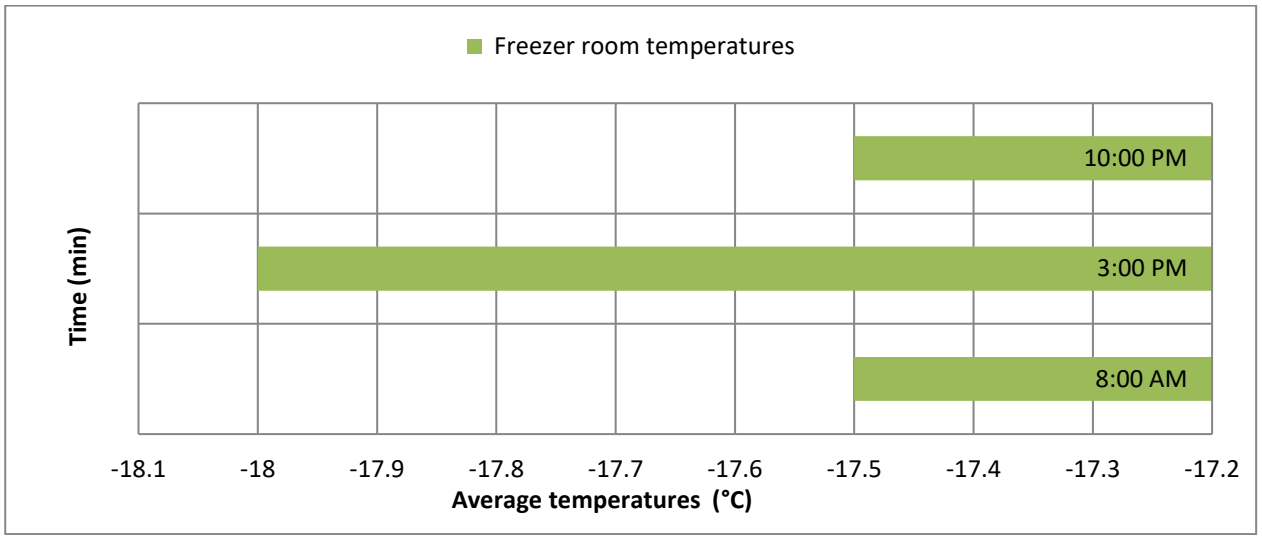

Fig. 14. The relationship between temperature and time in cooling room
Source: Author's determination.

Figure 15 and Table 1 show the average temperature across three sides of the smoking room, which ranged during the left side from 17.42 to 19.62 ºC, ranged during the front side from 16.08 to 17.62 ºC, and ranged during the right sides from 17.62 to 18.12 ºC.

Table 1. Three sides of the Smoking-room temperatures

Lift side		Front side		Right side	
	Average temperature		Average temperature		Average temperature
T1	17.42	T10	16.74	T19	18.12
T2	18.52	T11	16.52	T20	17.82
T3	19.12	T12	16.08	T21	18.02
T4	18.12	T13	17.54	T22	18.12
T5	19.02	T14	16.82	T23	18.12
T6	18.42	T15	16.66	T24	18.12
T7	18.02	T16	16.96	T25	17.82
T8	19.62	T17	17.62	T26	17.72
T9	18.12	T18	16.32	T27	17.62

Source: Author's determination.

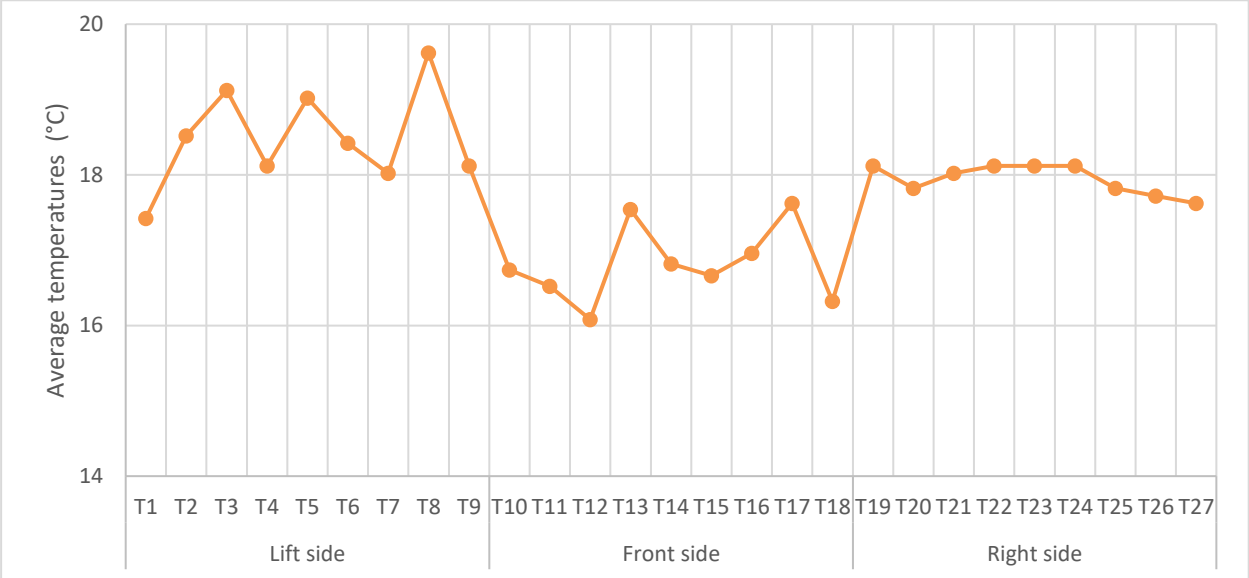

Fig. 15. The relationship between averagetemperature and three sides of the Smoking-room
Source: Author's determination.

CONCLUSIONS

A thermal imaging camera and associated software, which act as non-contact sensors, can be used to perform complete inspections and temperature measurements during salmon smoking operations.The results showed that the average temperature inside the smoking room, which ranged from 21.34 to 23.34 °C, and was between 0 and 1 °C inside the cooling room, while inside the freezing room, which ranged from -17.5 to -18 °C.

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