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The Effect of Microwave Application on the Drying of Banana (*Musa paradisiaca formatypica*) Flour Inoculated by *Cronobacter sakazakii* Bacteria

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ABSTRACT

Background: Instant baby porridge contains ingredients that allow it to be served instantly, eliminating the need for lengthy cooking process as the case with traditional porridges. Thanks to the 88.00% carbohydrates that it contains, banana flour can be utilized for instant baby porridge. As in the process of producing any flour, drying is a critical phase in the production of banana flour. According to previous studies *Cronobacter sakazakii* bacteria are resistant to drying. The purpose of this research is to determine the effect of Power level and length of drying in the microwave on the total reduction of *Cronobacter sakazakii* bacteria and to determine the combination of microwave power and duration, which results in the most elevated total reduction of *Cronobacter sakazakii* bacteria.

Methods: A completely randomized design (CRD) was employed in this investigation and microwave power was the first component. (100, 200, 300 watts) and the second factor being drying duration (10s, 20s, 30s).

Result: The research findings indicated that the microwave power and drying time and their interactions affected the total reduction of *Cronobacter sakazakii* bacteria. The greatest decrease in total *Cronobacter sakazakii* bacteria was found in the treatment of 300 watts for 30 seconds at a total microbe of 4.75 log CFU/g, color for lightness (L*) 75.76; for redness (a*) +2.98; for yellowness (b*) +16.42; ash content of 3.45%; amount of protein of 3.04%; content of fat 0.67% and carbohydrates content of 84%.

Key words: Banana flour, *Cronobacter sakazakii*, Dryer, Microwave duration, Microwave power, Microwave.

INTRODUCTION

Cronobacter sakazakii, formerly named *Enterobacter sakazakii*, infects mainly newborns and infants Chiang *et al.* (2023). It can cause meningitis, necrotizing enterocolitis and bacteremia, at a mortality rate of about 40 to 80% (Fu and Jiang, 2020). However, most of the reported disease cases are caused by *C. sakazakii* in infants under two months old (Gedifmeseret, 2020). Premature babies and infants with underlying medical conditions are at the highest risk of developing the disease. Several outbreaks caused by *C. sakazakii* have been traced to a contaminated powder formula (Forsythe, 2018).

Powdered infant formula (PIF) is the most widely used alternative to newborn feeding as its use rapidly increases. The microbiological quality and safety of PIF directly affect the health of infants (Zheng *et al*., 2021). However, infant formulas are used when breastfeeding is not possible (Kent *et al*., 2015). Nevertheless, the use of infant cereal feeding, even for those less than six months old, is common in the least developed and developing countries (Carvalho *et al*., 2020). One of the three PIF flavors that babies love is banana. In addition to its distinctive fragrant aroma, banana has incredible nutritional content, including the energy provided from its high carbohydrate content. Banana contains 120 calories and has various vitamins and minerals (Pratiwi and Krisbianto, 2019).

The minerals include potassium, magnesium, phosphorus, iron and calcium (Kumara *et al.,* 2020). Meanwhile, the vitamins it contains include vitamins C, B complex, B6 and serotonin, which are active as neurotransmitters in the smooth functioning of the brain (Intan, 2019). Furthermore, banana is one of the best sources of potassium, an essential mineral for maintaining normal blood pressure and heart function and act as an energy booster (Oshaba *et al*., 2021; Pratiwi and Krisbianto, 2019). The relatively high starch contained in bananas at

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30 mg/100 g makes it suitable to be turned into flour. Banana flour is perfect for digestion; hence it can be used to feed babies (Kosnayani Ai Sri, 2018). Banana flour can be produced from all species of bananas. However, with its highest carbohydrate content at 88.00%, the yellow banana is the best for flour raw materials compared to Jansen, Mali and Raja Nangka bananas. Apart from that, in terms of color, this banana is better than the other three bananas (Michalak *et al.,* 2020).

The use of microwave (MW) technology for commercially sterilizing products has been recently approved by FDA (Mardaneh and Soltan Dallal, 2017). Moreover, it is widely used in food heating. One of the issues in such process is the heating of materials by the existing radiation, in which heat penetrates directly into the foods, unlike water baths (Swarnakar, 2019) (Pina-Pérez *et al*., 2016). Thus, in MW, water is the primary component that allows food to be heated by microwaves (Kalla and Devaraju, 2017; Kooner *et al.,* 2023). Foods are subjected to intense heat, affecting their sensory and nutritional characteristics when compared to conventional heating (Lule and Koyuncu, 2017; Khalid *et al.,* 2023). However, the heating system can be switched on or off immediately, increasing the energy efficiency of the process (Hidayana *et al.,* 2022). Yet, the main problem with MW heating is uneven temperature distribution on the product (Khalid *et al.,* 2023). Eliminating this problem is a crucial point for using this technology since it can affect the product's sensory characteristics and microbiological stability (Parra-Flores *et al.,* 2021). The mechanism to inactivate microorganisms by microwave heating has been extensively studied and debated for more than half a century (Osaili *et al.,* 2021). There is, however, a universal agreement that the microwaves' primary mechanism for microbial inactivation is heating. The mechanism that contributes to this inactivation is called "non-thermal" effects caused by microwave fields and it has been discussed intensively (Song *et al.,* 2018). The primary aim of this study is to examine the impact of power, drying duration and their interactions on the decrease in total *C. sakazakii* bacteria in banana flour inoculated with *Cronobacter sakazakii* bacteria and to identify the combination of power and drying time treatments that leads to the maximum reduction in total *Cronobacter sakazakii* bacteria.

MATERIALS AND METHODS

The research was conducted at Jenderal Soedirman University, Purwokerto, Central Java, Indonesia from September, 2023 to February, 2024.

Banana flour

Before being processed into flour, old but unripe yellow bananas with their green and hard skin were steamed for 10 minutes, then peeled, cut into thin, elongated pieces to ±0.5 cm thick and cleaned of seeds (Fida *et al.,* 2020). Then, the cleaned bananas were flowed in a citric acid solution of 1.5-2 g/L for 15 minutes and drained. Later, it was dried using a cabinet dryer for 6 hours at 60°C (Dibakoane *et al.,* 2023). The banana was dry when it could be easily damaged (moisture content around 6-10%) and then ground with a disc mill and sieved to a fineness of 80 meshes (Yasin, 2018).

Bacteria inoculum preparation

Bacterial isolate *Cronobacter sakazakii* FWHd16 from frozen stock was revitalized by smashing it on TSA (Tryptic Soy Agar) medium with the addition of ampicillin (TSAA) (Li *et al.,* 2020). The bacteria were incubated in an incubator at 37°C for 24 hours. The isolates confirmed on TSAA were then suspended in 15 ml of BPW, put into a centrifuge tube and centrifuged at 4000 rpm for 15 minutes at 4°C. The cell pellet formed was separated from the supernatant and then the pellet was suspended in 1 ml BPW and the inoculum was ready for use (Sinaga *et al.,* 2016).

Inoculums calculate

Calculations were made by growing 1 ml of suspension on TSAA media after multilevel dilution with BPW diluent until the dilution level was estimated at 10^7 CFU/ml. Incubation was carried out for 24 hours at 37°C. Colonies were counted using the Standard Plate Count formula (Sinaga *et al.,* 2016).

Banana flour inoculation

The flour was inspected and the negative form of *C. sakazakii* was clarified. The inoculum suspension was added with 5 ml of banana flour for 10 grams of banana flour. Then, it was mixed to get inoculated banana flour.

Experimental design

The experimental design used was a completely randomized design (CRD), which consisted of two factors: microwave power (100, 200 and 300 watts) and drying time (10, 20 and 30 seconds). The treatments were arranged in such a way that nine treatments were obtained; each combination was repeated three times to obtain 27 experimental units (Table 1).

Data analysis

The data were analyzed using ANOVA at a 95% confidence level, followed by Duncan's Multiple Range Test (DMRT) at a 5% level if significant effects were found. The most effective treatment was determined based on the total reduction of Cronobacter sakazakii bacteria. After selecting the best treatment, its physical and chemical characteristics, along with the total bacterial count, were compared to the control using a Paired T-test at a 95% confidence level.

RESULTS AND DISCUSSION

Total decline in *Cronobacter sakazakii*

Based on the ANOVA results, it was found that the microwave power (P) and drying time (T) and their interaction (P*T) significantly affected the total decrease in *C. sakazakii* bacteria (Table 2).

The electromagnetic energy from the microwave had a negative charge on one side and a positive one on the other (Zheng *et al.,* 2021). As a result, the changing electric field induced *via* microwaves on each side led to the rotation of molecules in the material to align themselves with each other (Khalid *et al.,* 2023). This formed heat as a result of friction between molecules (Michalak *et al.,* 2020). The decrease in total bacteria was probably due to the thermal effect produced by microwave radiation. The thermal effect occurred because molecules in food absorb Different heat from the one generated by the microwaves (Kandasamy and Sarkar, 2019). According to Bhatt *et al.* (2020), electromagnetic waves could also damage the structure of the outer layer of bacterial membrane. The stability, function and denaturation of essential bacterial proteins and DNA would be damaged by it. Electromagnetic directly affected the reduction of *C. sakazakii* bacteria in banana flour. As shown in Fig 1 the P3T3 treatment was the treatment that had the most subordinate total *C. sakazakii* at 5.32 log CFU/g. However, this amount was still higher than the requirements for microbial contamination in banana flour based on Indonesian National Standard or SNI (4 log CFU/g). At 24%, P3T3 treatment had the highest reduction in total *C. sakazakii* bacteria than the other treatments. Therefore, P3T3 treatment was chosen as the best treatment for further analysis in the study's second phase.

Table 1: Treatment combination.

Microwave power (P)	Drying time (T)		
	T1	T2	T3
P1	P1T1	P1T2	P1T3
P2	P2T1	P 2T2	P2T3
P3	P3T1	P3T2	P3T3

Information:

P1, P2, P3: Level of microwave power element.

T1, T2, T3: Level of drying time.

P1T1, P3T3: Combination of treatments.

Table 2: Decrease in total *Cronobacter sakazakii* bacteria.

Treatment	Total bacteria *C. sakazakii* (logCFU/g)	Bacteria *C. sakazakii* decrease (%)
Inoculation	7	
P1T1	6.84	2.29
P1T2	6.82	2.57
P1T3	6.79	3
P2T1	6.74	3.71
P2T2	6.68	18.85
P2T3	5.57	20.43
P3T1	5.46	22
P3T2	5.40	22.86
P3T3	5.32	24

Color analysis L* (lightness)

The analysis results using the Paired T-test at 95% confidence level showed a significant difference in the L* value between P0T0 and P3T3 treatments.

Fig 2 illustrates the decrease in the L* value of Banana flour was A 1.71% . This decrease in the L* value in banana flour was believed to be caused by the heat generated from the microwave Peralta-Ruiz *et al.* (2020). The higher the power that the microwave used, the longer the cooking time would be. As the microwave material got hotter, the color would turn brown. Rostianti *et al.* (2018) stated that the brightness of the color in food was affected by the hydrolysis processes and enzymatic reactions.

a* (redness)

The analysis results using the paired T-test at 95% confidence level showed that no significant difference in the a* value between P0T0 and P3T3 treatments was found.

The data presented in Fig 3 demonstrate the a* value of banana flour increased by 23.14%. According to Rasyid *et al.* (2017), the change in a* value after microwaving was caused by a reaction between reducing sugars and free

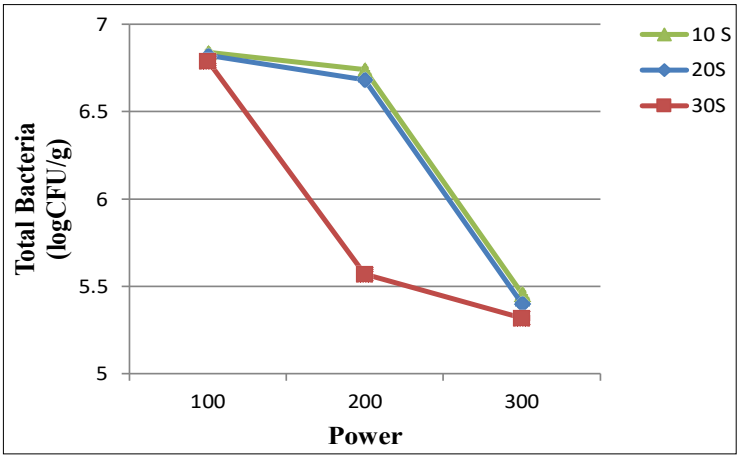


Fig 1: Chart showing the total reduction of *Cronobacter sakazakii.*

amine groups from amino acids or proteins. In other words, a Maillard reaction occurred during the microwave treatment. The insignificant increase in a* value between the two treatments was believed to be caused by the microwave treatment on banana flour, which maintained the red color of banana flour.

b* (yellowness)

The analysis results using the Paired T-test at 95% confidence level showed no significant difference in the b* value between P0T0 and P3T3 treatments.

Fig 4 highlights the decrease was o A 3% decrease was observed in the b* value of banana flour. This decrease in the b* value was in line with Shabrina and Susanto, (2017) states that the higher the temperature and the longer the drying time were, the less yellowish the color would be. This decrease was caused by browning in foodstuffs, where the process of forming yellow pigments would turn brown (Hidayana *et al*., 2022).

Ash content

The analysis using the paired T-test at 95% confidence level showed no significant difference in the ash content between P0T0 and P3T3 treatments.

With the microwave treatment, as depicted in Fig 5 there was an average increase in the ash content of banana flour by 8.83%. According to Zahroh (2015), states that the lower the percentage of water content in flour, the higher the ash content. In addition, the longer and higher the drying temperature will be able to increase the ash content because the water content that comes out of the material is more significant (Erni *et al*., 2018).

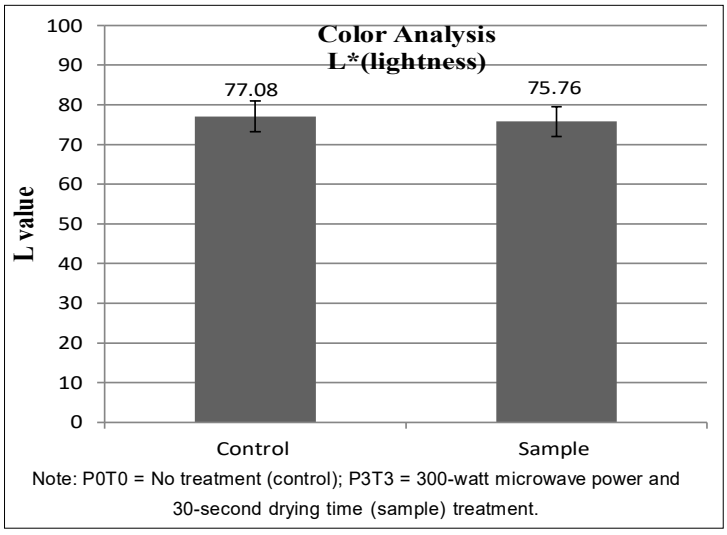


Fig 2: Average L* value of banana flour without treatment and with the best treatment.

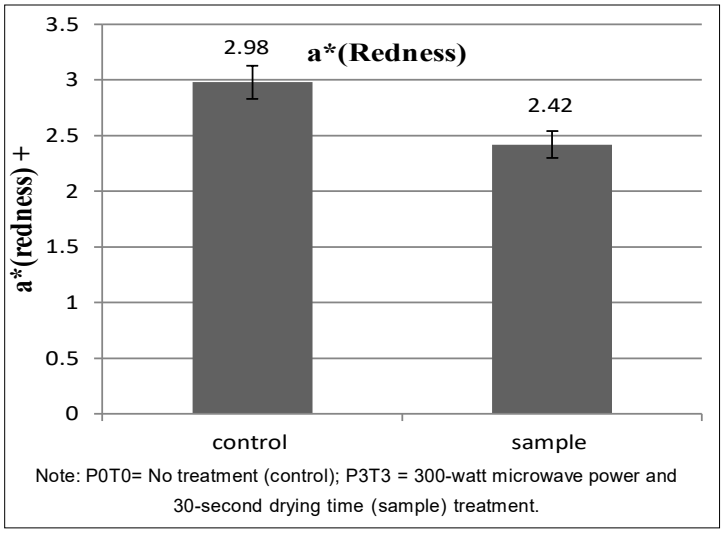


Fig 3: Average a* value of banana flour without treatment and with the best treatment.

Protein content

The analysis results with the Paired T-test on 95% confidence level showed that there was a significant difference in protein content between P0T0 and P3T3 treatments.

The results in Fig 6 reveal to an average 22.45% decrease in the protein content of banana flour (Cato *et al.,* 2015). Allegedly this was because during the heating process in microwave, the protein in banana flour underwent a coagulation process which reduced the binding capacity of the protein to water and dissolved with water (Nisa *et al.,* 2020).

Fat content

The analysis using the paired T-test at 95% confidence level showed a significant difference in fat content between P0T0 and P3T3 treatments.

The data presented in Fig 7 demonstrate an average 17.28% decrease in the fat content of banana flour. According to Lisa *et al.* (2015), the very low-fat content means that the flour produced is not easily damaged (rancid) due to oxidation reactions so it can be stored for a long time. The microwave treatment caused the banana flour to increase in temperature. It was suspected that the

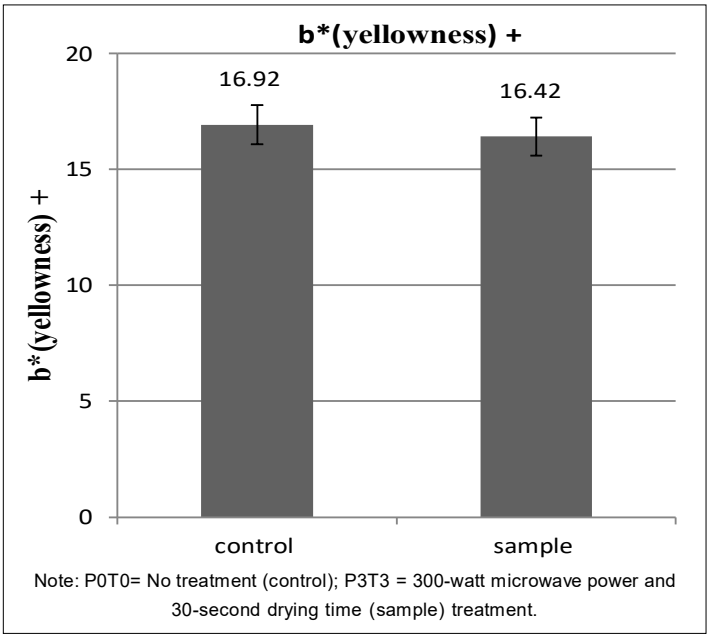


Fig 4: Average b* value of banana flour without treatment and with the best treatment.

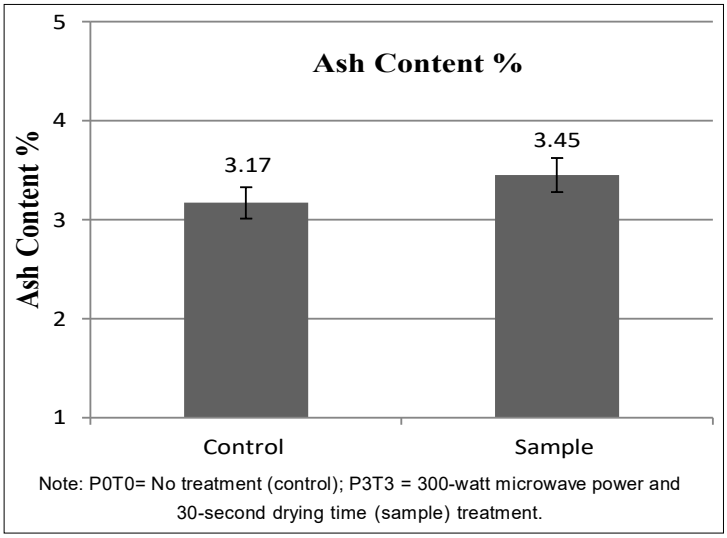


Fig 5: The average value of ash content of banana flour without treatment and with the best treatment.

fat content in banana flour was damaged by heat (thermal degradation). In other words, the fat content in banana flour decreased because the fat underwent an oxidation.

Carbohydrate content

The analysis using the paired T-test at 95% confidence level showed a significant difference in carbohydrate content between P0T0 and P3T3 treatments.

As depicted in Fig 8 shows the average value of carbohydrate content for banana flour without treatment/ control (D0L0) is 82.77% and treatment with 300-watt microwave power with a microwave time of 30 seconds (D3L3) is 84%. This is not much different from research by Suryani *et al.* (2018), the nutritional content of banana flour contains 88.60% carbohydrates.

A 1.49% increase in carbohydrate content was observed. This increase caused the carbohydrate content to fluctuate and the content of other nutrients to decrease thanks to the carbohydrates' high dependence on the reduction factor (by difference) Rostianti *et al.* (2018).

Total plate count (TPC)

The analysis results using the paired T-test at 95% confidence level showed a significant difference in the TPC value between P0T0 and P3T3 treatments.

As outlined in Fig 9 there was a decrease in the TPC value of banana flour by 21.62%. The decrease in the TPC value of banana flour is thought to be due to the microwave treatment.

According to Najmina *et al.* (2014) the damage caused by microwave radiation to bacteria can even reach their DNA structure. It can, therefore, be ascertained that all pathogenic bacteria will die, enzymes will become inactive and even damage spores. The 300-Watt microwave power

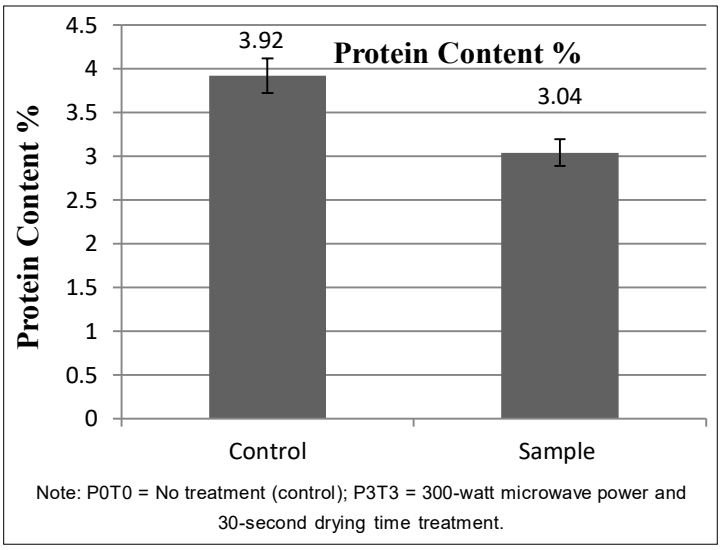


Fig 6: Average protein content of bananas without treatment and with the best treatment.

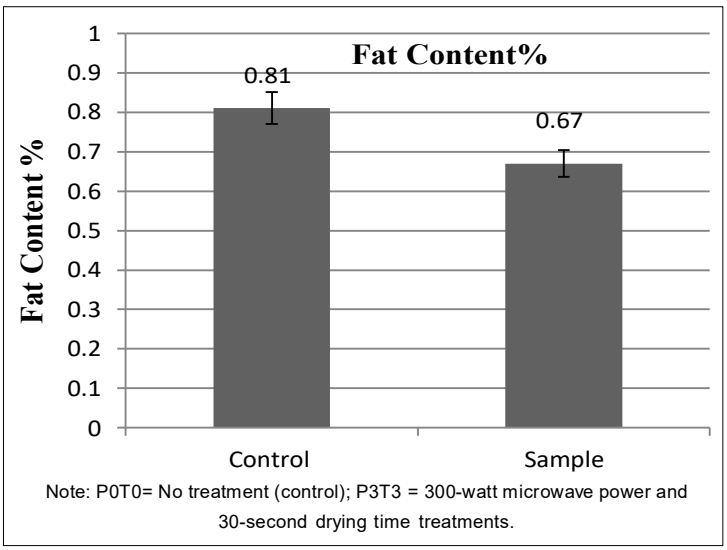


Fig 7: Average fat content of bananas without treatment and with the best treatment.

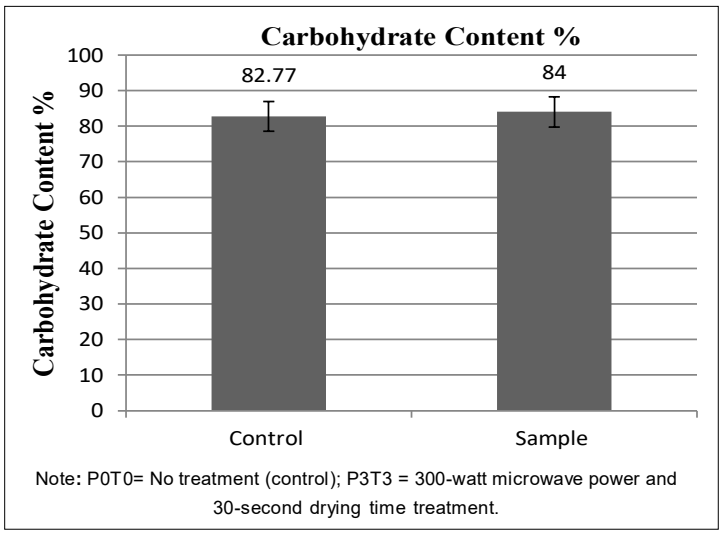


Fig 8: The average carbohydrate content of bananas without treatment and with the best treatment.

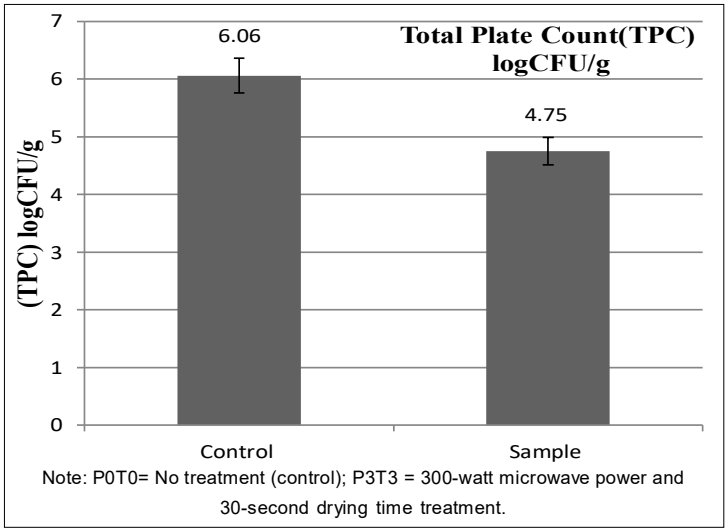


Fig 9: The average TPC value of bananas without treatment and with the best treatment.

and 30-second drying time resulted in the most elevated total reduction of *Cronobacter sakazakii* bacteria in banana flour at 24% with Total microbial characteristics (TPC) of 4.75 logs CFU/g, color for L* (lightness) 75,76; for a* (redness) +2.98; for b* (yellowness) +16.42; ash 3.45%; protein 3.04%; fat 0.67%; and 84% carbohydrates.

CONCLUSION

The study demonstrates that both microwave power and drying duration significantly impact the reduction of *Cronobacter sakazakii* bacteria. The most effective treatment, using 300 watts for 30 seconds, resulted in a substantial bacterial reduction, with the bacterial load decreasing to 4.75 log CFU/g. This treatment also maintained acceptable product quality, as indicated by the color parameters (lightness L*, redness a*, yellowness b*) and preserved the nutritional content, including ash, protein, fat and carbohydrates. Overall, the findings suggest that microwave drying at 300 watts for 30 seconds is an effective method for reducing *Cronobacter sakazakii* while maintaining product quality.

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Conflict of interest

The authors declare that they have no conflicts of interest relevant to this study.

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