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The Effect of Sterility Values and Retort Temperatures on the Change of Physical and Sensory Properties of a Canned Mushroom Product

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Abstract

This research aimed to study the effect of sterility values on physical quality (drained weight, brown colour index, and texture) and sensory properties of canned *Agaricus bisporus* mushrooms processed at different retort temperatures (115, 121, and 130 ^{o}C) and processing times (2-97 minutes). Mushrooms in brine solution media packaged in 300x407 cans were heated in industrial-scale horizontal static retorts at different retort temperatures for specific processing times to reach different F_0-values. The canning process was carried out following commercial production procedures in one of the mushroom canning factories. Measurement of heat penetration into the product was carried out using a protocol established by the Institute of Thermal Process Specialists (IFTPS), and the sterility values (F_0) were calculated. Our results indicated that the physical and sensory properties of canned mushrooms were not only affected by sterility value but also by the combination of temperature and time used to process the product. At the same level of sterility, a higher retort temperature (130 ^{o}C) resulted in canned mushroom with a lower browning rate, an improved texture profile (decreased hardness, increased chewiness, and shear force), a sweeter taste, and increased intensity of umami taste. However, the canning process at a temperature of 130 ^{o}C resulted in a greater reduction of the drained weight as compared to that of canning at 115 ^{o}C and 121 ^{o}C.

Keywords: *Agaricus bisporus*; Canning; Browning colour index; Drained weight; Sensory; Texture

1 Introduction

Agaricus bisporus is one of the most popular edible mushrooms (Kumar et al., 2017) and accounts for 30% of total mushroom production in the world (Royse, 2014). This mushroom has a high economic value because of its nutritional content, functional properties from its bioactive compounds, and unique taste (Zhang et al., 2018). Mushrooms are a potential source of essential nutrients, such as carbohydrates, proteins, dietary fibre, phenolic compounds, polyunsaturated fatty acids, vitamins, and minerals (Ramos et al., 2019). However, fresh *A. bisporus* is highly perishable by nature and has a short

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shelf-life in the ambient environment, owing to its high moisture content, lack of physical protection to avoid water loss or microbial attack (Fernandes et al., 2012; Joshi et al., 2018) and extreme sensitivity to heating (Xue et al., 2017). Thermal processes, including canning, are widely applied by the mushroom processing industry to extend the shelf-life, which is cost-effective (Tola & Ramaswamy, 2018). The primary concern when designing a sterilization process is the inactivation of pathogenic microorganisms to protect public health. The desired lethal effect on pathogenic microorganisms can be achieved through a wide range of time-temperature combinations. However, the heat process targeted to inactivate pathogenic microorganisms also results in various physical and sensory quality degradations. The optimum sterilization process is required to maintain the quality of the product without compromising food safety aspects (Ling et al., 2015).

During the sterilization process, the effect of temperature and heating time on pathogenic microorganisms is commonly represented by the F_0-value. It can be defined as the equivalent heating time at a temperature of 121.1 ^{o}C. Previous researchers have reported the impact of commercial sterilization or canning on physical and sensory properties. Anantheswaran et al. (1986) reported that heating mushrooms at the temperature of 110-129.4 ^{o}C for 8-46 minutes decreased the whiteness, yield, and texture. Moreover, Jaworska et al. (2010) showed that sterilization of different mushrooms at atemperatures of 100-121 ^{o}C caused a significant decrease in hardness of up to 92%. Sun et al. (2014) also reported that pressure-cooking significantly affects the texture and chemical composition of processed products. On the other hand, the change of organoleptic attributes as the impact of high-temperature processes was also reported by Jaworska et al. (2011) and Liu et al. (2014). However, it is still arguable whether the change of physical quality and sensory attributes due to sterilization could also be solely described as a function of the F_0-value. Limited data is available to systematically explore the impact of time-temperature on mushrooms. Therefore, this research aimed to study the effects of sterility values (F_0-values) and retort temperatures of various time-temperature combinations on physical quality (drained weight, colour, texture) and sensory properties of canned *A. bisporus* mushrooms.

2 Materials and Methods

2.1 Materials

Fresh white button mushrooms (*A. bisporus*) cultivated in Probolinggo, East Java, Indonesia were kept fresh by storing at 4 ^{o}C for one day before being processed. A horizontal static retort with a diameter of 1.25 m and a length of 2.35 m (Chi Yinfa, Taiwan) was used as the equipment. Temperature measurement and recording were done using the OM-CP-Hitemp140 data logger (Omega Engineering, Norwalk, Connecticut, USA), which could measure temperatures up to 140 ^{o}C, with an accuracy of $\pm$0.1 ^{o}C.

2.2 Canning procedure

Preparation of *A. bisporus* samples before canning followed the procedure used in one of the mushroom canning factories (PT. Suryajaya Abadiperkasa, Probolinggo, East Java, Indonesia). Mushrooms were stored one day at a temperature of 3-5 ^{o}C before the canning process. In general, the canning steps were material preparation, blanching, filling into cans, filling medium (citric acid, ascorbic acid, and NaCl), exhausting, seaming, sterilizing, cooling, and storing (Figure 1). The retort consisted of three baskets loaded randomly with the cans. Each basket was filled with 700 cans (full capacity conditions). Control mushroom samples were taken shortly after the seaming process or just before the retorting process. In contrast, the treated product samples were taken after the sterilization process according to the design of the experiment at different retort temperatures (115, 121, and 130 ^{o}C). The canning process was carried out in duplicate.

2.3 F_0-value calculation

F_0-value was calculated based on heat penetration data. Heat penetration tests were carried

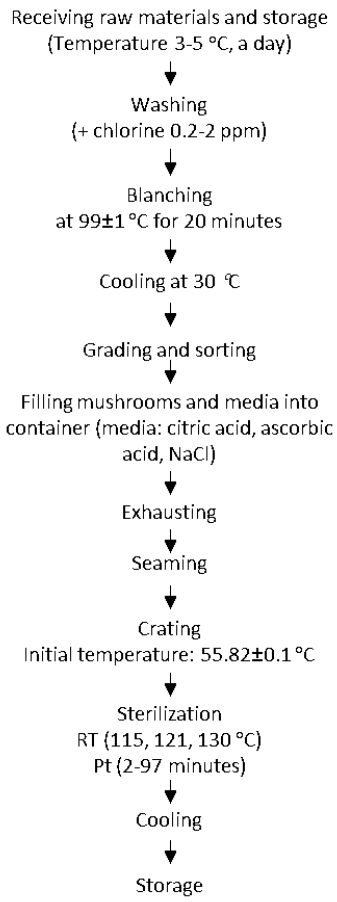

Figure 1: Flow chart of the canning process of the *A. bisporus* mushroom (Pursito et al., 2020)

out by placing eleven data loggers (OM-CP-Hitemp 140, Omega Engineering, Norwalk, Connecticut, USA) in the slowest heating area. Data loggers were located at the centre of the cans, and their sensors were inserted into the mushrooms. Sterility value was expressed as a F_0 calculated using the General Method (Holdsworth & Simpson, 2016), as shown in Equation 1.

$$F_0 = \int_0^t 10^{\frac{T-T_{ref}}{z}} dt \tag{1}$$

where F_0 was the equivalent heating time (in minutes) at a constant temperature of 121.1 ^{o}C to inactivate *C. botulinum* spores, T was the product's temperature at any given time; T_{ref} was a reference processing temperature (121.1 ^{o}C), and z was 10 ^{o}C. Datalogger placement schemes and samples on a static horizontal retort are shown in Figure 2.

2.4 Drained weight calculation

Drained weight was measured in triplicate (AOAC International, 1984). The samples were drained on an eight-mesh stainless steel filter (Fisher Scientific Company, USA) for two minutes with a 20^o slope angle at room temperature (25 ^{o}C). The calculation of drained weight was based on Equation 2.

$$Drained\ weight = \frac{yield}{net\ weight\ of\ can\ content} \times 100 \tag{2}$$

2.5 Texture analysis

The texture measurement was performed by using the TA-XT2i Texture Analyzer (Stable Micro Systems Ltd., Godalming, Surrey, UK) with a cylindrical probe (diameter of 35 mm), by performing texture profile analysis (TPA), as shown in Figure 3A. The mushroom samples were measured in triplicate. Samples were cut to have uniform dimensions of 20 mm x 20 mm x 18 mm. For the TPA test, the samples were pressed twice at a crosshead speed of 1 mm sec^{-1}, deformation level 60%, and a time interval of 20 seconds between compressions. Textural parameters of hardness and chewiness were recorded from the force–deformation curve. Shear force test was carried out by using a Warner-Bratzler Shear Cell (Figure 3B). Texture parameters from TPA and shear force tests were obtained using Texture Expert 1.22 software (Stable Micro System Ltd, Scarsdale, NY).

2.6 Colour Analysis

Analysis of visual colour was performed by using CR310 Chromameter (Konica, Minolta, Tokyo, Japan). Hunter's colour parameters (L, a, and b values) for the surface of treated mushroom samples (caps) were recorded (Mihalcea et al., 2016). The colour was measured in triplicate. The L-value indicated lightness, a, the red (+) or green

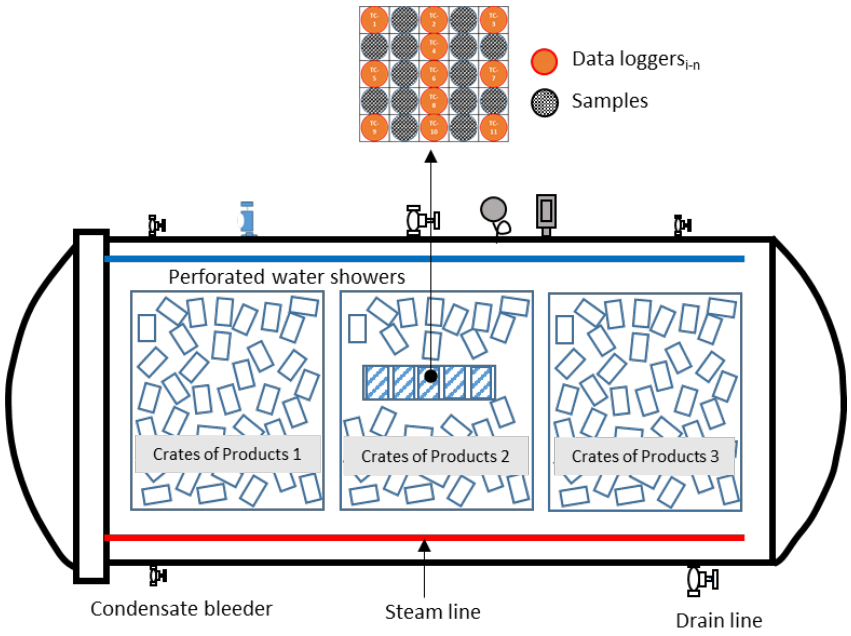

Figure 2: Datalogger placement schemes and samples on static horizontal retort (Pursito et al., 2020)

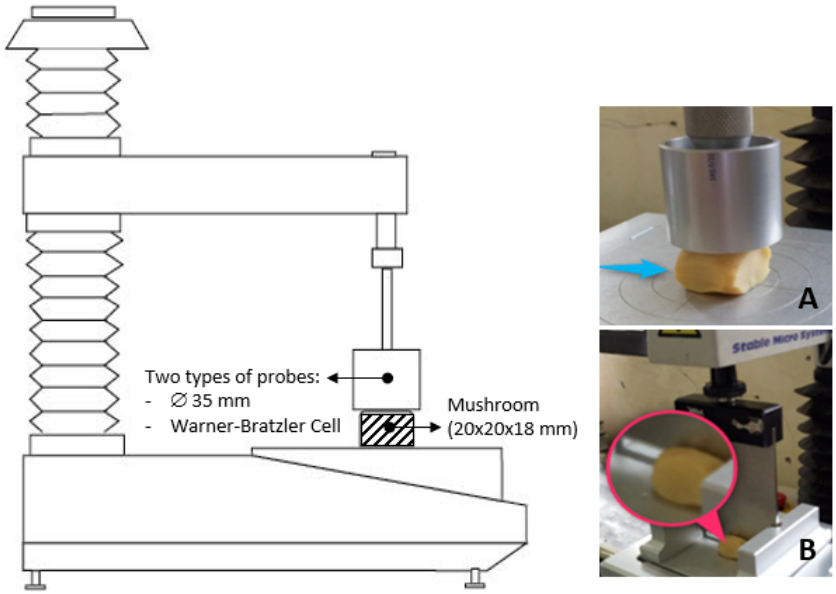

Figure 3: Measurement with a texture analyzer model XT2i type probe with diameter of 35 mm (A) and Warner-Bratzler (B).

(-) coordinate, and b, the yellow (+) or blue (-) coordinate. The Browning Colour Index (BCI), representing the purity of brown colour (Gao et al., 2014), was calculated from equation 3.

$$BCI = [100(x - 0.31)]/0.172 \quad (3)$$

Where x= (a+1.75L)/(5.645L+a-3.012b)
"L" is the brightness (lightness), "a" is the colour of reddish-green (greenness/redness), and "b" is the colour of bluish yellow (yellowness/blueness).

2.7 Sensory Evaluation

The control samples were thawed and conditioned at room temperature (25 ^{o}C). Samples were boiled for 10 minutes, cooled at 25 ^{o}C, and blended for 20 seconds. Samples (30 g each) were presented on white plates, each with a total of 4 test samples and one reference (control) sample together with water, white bread, and tissue paper (Figure 4). Each sample container was given a three-digit random number as the sample code. Each sample was tested triplicate and repeated on different days.
Sensory tests were carried out in a sensory laboratory at room temperature conditions, with sufficient light, and ventilation. Based on the screening tests, panellists were selected from professional assessors. Eleven trained panellists consisting of nine females and two males, 24-46 years old were involved in this sensory test. There was a discussion and re-training on scalar scoring methods in all group discussions on the basic quality parameters of taste (umami, salty, sour, sweet, and bitter). Determination of the standard value/reference (control) of taste was determined based on focus group discussion on the taste of salty, sour, sweet, bitter, and umami. In particular, umami taste intensity was trained to differ in the gradations of 6 concentrations of MSG standard solutions 0.03, 0.09, 0.15, 0.21, 0.27, or 0.30 g/100 mL (Phat et al., 2016). Panellists evaluated the intensity of flavours using a non-structured line scale of 1-15. The sensory assessment results were transformed on a scale of 0-100 where 0 = no taste and 100 = extreme intensity.

2.8 Statistical Analysis

The physical quality and sensory evaluations were analyzed by regression and descriptive analysis methods using MS Office Excel (2016) for each temperature (115, 121, and 130 ^{o}C) and sterility values. The rate of change of the values of the quality parameters (drained weight, colour, texture, and sensory attributes) were determined from the gradient of each regression line.

3 Results and Discussion

3.1 Drained Weight

The canning of mushrooms induces significant changes in their physical and chemical properties. One of the most critical changes is water loss from the mushroom, which causes a loss of weight and a reduction of the net weight in the can. These losses have a significant economic repercussion (Vivar-Quintana et al., 1999). Figure 5 shows the effects of retort temperatures (115, 121, and 130 ^{o}C) an F_0-values on the drained weight. Samples with a value of F_0=0 minutes are control samples, which were taken before the retorting process. The drained weight decreased exponentially with increasing F_0-values at all sterilization temperatures. The result also showed that retort temperature significantly influenced the change in the drained weight of the product. The rate of decline at retort temperature of 130 ^{o}C was slightly higher than that at the retort temperatures of 121 and 115 ^{o}C. At the same F_0-value, for example 10 minutes, the percentage of drained weight at 115, 121, and 130 ^{o}C were 48.84%, 48.45%, and 47.86%, respectively. Retorting the product at 115 ^{o}C and 121 ^{o}C is expected to give the drained weight reduction of 0.18 – 0.19% from that of the control sample. On the other hand, retorting the product at 130 ^{o}C would result in a drained weight reduction of 0.99%.
A decrease in drained weight occurred at higher temperatures probably because the higher retort temperature (130 ^{o}C) caused more cell wall damage as compared to the lower retort temperature. At higher temperatures, the cell and tissue

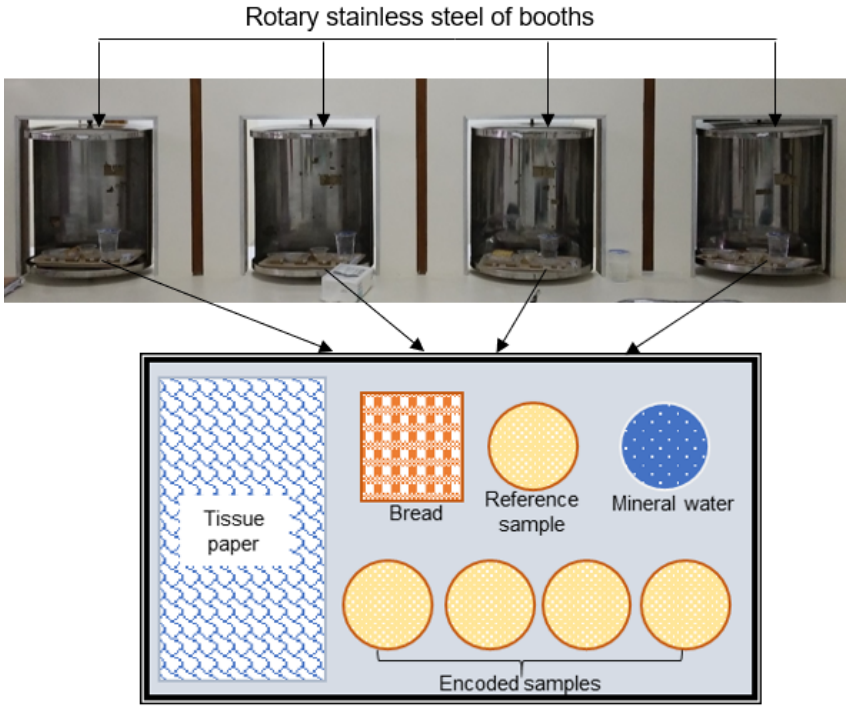

Figure 4: Sensory booths and details of sample presentation

structure shrinks and releases water contained in the tissue (Almonacid et al., 2012). Canning also causes protein denaturation and leads to decreased yield. A decrease of drained weight due to canning (high temperature) was also reported by Anantheswaran et al. (1986) and Paudel et al. (2016). The loss of water holding capacity after heat treatment was correlated mainly with the loss of cell membrane integrity.

3.2 Colour

The quality of the mushrooms is determined by the colour, which is one of the most crucial parameters that influence consumers' choices and preferences of foods. Browning on mushrooms reduces the selling value of the product. In general, the brighter colour of mushrooms is preferred by consumers so that it has higher economic value (Chen et al., 2018). The change in food colour during a thermal process is influenced by various mechanisms, such as degradation of pigments, oxidation of ascorbic acid, enzymatic browning, and non-enzymatic browning (Ling et al., 2015). Figure 6 shows the effect of F_0-values at different retort temperatures (115, 121, 130 ^{o}C) on the Browning Colour Index (BCI) of canned *A. bisporus*.

BCI values increased with the increase of F_0-values at all sterilization temperatures (115, 121, 130 ^{o}C). At the same F_0-value, for example, at the F_0-value of 10 minutes, retort temperatures of 115, 121, and 130 ^{o}C, the BCI values were 10.54, 11.86, and 10.52, respectively. Therefore, sterilization at a retort temperature of 130 ^{o}C gave a more favourable colour compared to the other two retort temperatures. The difference of BCI can be measured by comparing the BCI of certain F_0-value (for example, at the F_0-value of 10 minutes) and initial BCI (F_0-value of 0 minutes) at 115, 121, and 130 ^{o}C. At an F_0-value of 10 minutes, it was found that the BCI values of 115, 121, and 130 ^{o}C were 10.54, 11.86, and 10.52, respectively (Figure 6). Therefore, ther-

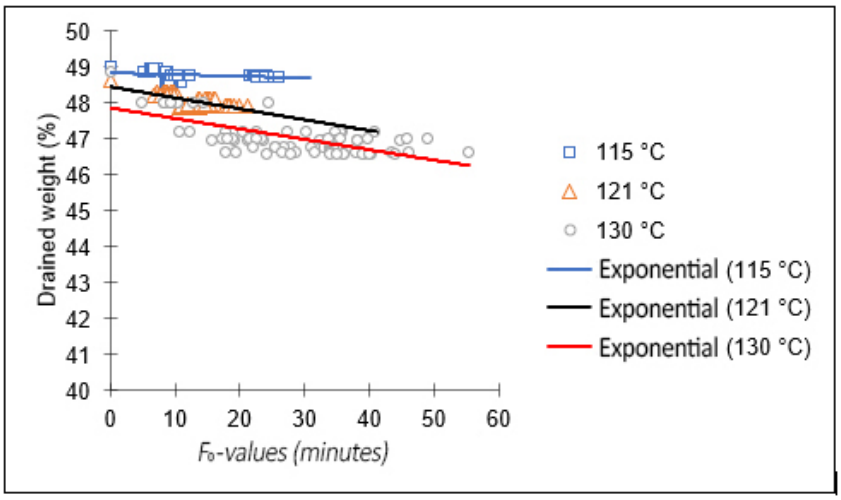

Figure 5: Effect of F_0-value at different retort temperatures (115, 121, and 130 ^{o}C) on drained-weight of canned *A. bisporus* mushroom packed in 300x407 can. The lines are lines of best fit.

mal treatment at 115 and 121 ^{o}Cwould give an increment of BCI of as much as 14.9 - 22.9%. However, retorting at 130 ^{o}Cwould result in a BCI increment of 4.8%. This result showed that sterilization at a retort temperature of 130 ^{o}C resulted in less colour change compared to that of the other retort temperatures.

The browning rate at retort temperature of 130 ^{o}Cwas lower than other retort temperatures because to achieve the same F_0-value, a higher temperature (130 ^{o}C) required less processing time compared with other retort temperatures (115 and 121 ^{o}C). Conversely, to achieve the same F_0-value, sterilization at retort temperatures of 115 and 121 ^{o}C required a longer time. A previous study by Pursito et al. (2020) showed that the times needed to achieve an F_0-value of 10 minutes at temperatures of 115, 121, and 130 ^{o}C were 39.32, 11.22, and 1.30 minutes, respectively.

An increase in BCI-values (Figure 6) may have been due to the impact of the retort temperature and processing times on non-enzymatic Maillard reaction. Ames (1990) and Jing and Kitts (2002) stated that the rate, extent, and course of Maillard reactions are influenced by several factors including, but not limited to, type of reactants, temperature/time combinations, pH, and water activity. An increase in temperature increases the rate of Maillard reaction. This reaction occurred in the canning process because mushrooms contain amino acids and reducing sugars, which are ingredients needed for the Maillard reaction. Maillard reactions led to changes in food colour, organoleptic properties, protein functionality, and protein digestibility (Lund & Ray, 2017). The Maillard reaction is of primary importance to the food manufacturer since it is frequently responsible for the aromas and colours that develop during the heating or storage of food products. Studies of model systems showed that an increase in temperature and/or time of heating resulted in increased colour development (Ames, 1990). Colourless solutions characterize the initial Maillard reaction, but after several reactions, a brown or black insoluble compound called melanoidin is formed (Awuah et al., 2007). Maillard browning can be inhibited by decreasing moisture to minimum levels or by increasing dilution, lowering pH, and temperature if the product is in the form of a liquid.

Due to the differences between *z-value* of *Clostridium botulinum* (z = 10 ^{o}C) with D_{121} = 0.25 minutes and the *z-value* of browning reaction z = 32 ^{o}C (Toledo et al., 2018), it is suggested that the activation energy of browning is lower than the deactivation of microbial activity

(*C. botulinum*). This value implies that the rate of destruction of microorganisms will be much higher than the rate of destruction of colour attributes at a higher temperature. Thus, the thermal processing of food products at higher temperatures can achieve commercial sterility with better retention of colour quality.

3.3 Texture

Hardness, chewiness, and shear force are essential attributes of mushroom texture among several other attributes. Figure 7 shows the effect of retort temperatures (115, 121, and 130 ^{o}C) and F_0-values on hardness. Compared with control samples, the hardness decreased quadratically with increasing F_0-values at all sterilization temperatures (115, 121, 130 ^{o}C). The reduction of hardness at 130 ^{o}C was lower than that at 121 and 115 ^{o}Cretort temperatures. The difference of hardness can be measured by comparing the hardness at a certain F_0-value (for example, at the F_0-value of 10 minutes) and initial hardness (F_0-value of 0 minutes) at 115, 121, and 130 ^{o}C. At an F_0-value of 10 minutes, it was calculated that the hardness values of 115, 121, and 130 ^{o}C were 5441.94 *gf*, 5480.59 *gf*, and 5738.59 *gf*, respectively (Figure 7). Therefore, treatment at 115 and 121 ^{o}C reduced the hardness by 11.6%, whereas the treatment of 130 ^{o}C reduced the mushroom hardness by 7.6%. It can be said that sterilization at a temperature of 130 ^{o}C caused less damage to hardness compared to other retort temperatures.

It was found (Figure 8) that the chewiness increased at higher F_0-values, which may have been due to the heat-induced cell decomposition and fragmentation during sterilization. At the same F_0-value (F_0-value of 10 minutes) at 115, 121, and 130 ^{o}C, the chewiness values were 2.084 *gf*, 2.077 *gf*, and 2.06 *gf*, respectively. Conversely, Jaworska et al. (2010) reported the reduction of chewiness after canning, but sterilization was carried out at temperatures up to 100-121 ^{o}C, 5-12 minutes of *Boletus edulis*. The canning process led to changes in the textural parameters depending on the species of mushroom.

The result of the texture testing using Warner-Bratzler shear cells is shown in Figure 9. The use of this blade is intended to resemble human incisors when used to cut mushrooms. Compared to the previous parameters of texture, the difference of shear force can be measured by comparing the shear force of certain F_0-value (for example at the F_0-value of 10 minutes) and initial shear force of control samples (F_0-value of 0 minutes) at 115, 121, and 130 ^{o}C. At an F_0-value of 10 minutes, the shear force of 115, 121, and 130 ^{o}C were 32,430, 31,852, and 24,088 *gf*, respectively (Figure 9). Therefore, thermal treatments at 115 and 121 ^{o}C would give a reduction of shear force of more than 140%, whereas the treatment of 130 ^{o}C would give a reduction of shear force less than 100% (78.6%). It can be seen that mushroom sterilization at a temperature of 130 ^{o}C would result in less shear force reduction compared to that of lower retort temperatures. Compared with control samples, this increasing trend of shear force was similar to the findings of a study reported by Anantheswaran et al. (1986). Generally, increased processing temperatures significantly affect mushroom texture (Zivanovic & Buescher, 2004). Figure 5 shows that a higher retort temperature (130 ^{o}C) resulted in a more significant effect on the reduction of drained weight due to cell integrity. Higher temperatures or longer canning processes cause more damage to the cell walls of mushroom tissue. It could impact changes in WHC during thermal processing, whereas, among the cell wall components in mushrooms, both chitin and protein contribute to water retention by providing mechanical strength to the cell wall (Paudel et al., 2016).

Furthermore, Jasinki et al. (1984) observed using transmission electron microscopy (TEM), that high temperatures during canning caused coagulation of cytoplasmic material and disruption of the intracellular membranes. Therefore, retorting might probably cause the loss of WHC of the tissue, which also affected the hardness, chewiness, and shear force (Figures 7, 8, and 9). For practical application, our findings agreed with those of Tang et al. (2014) who report that the higher sterilization temperature improves the textural as well as the colour and sensory acceptability of the retort processed product.

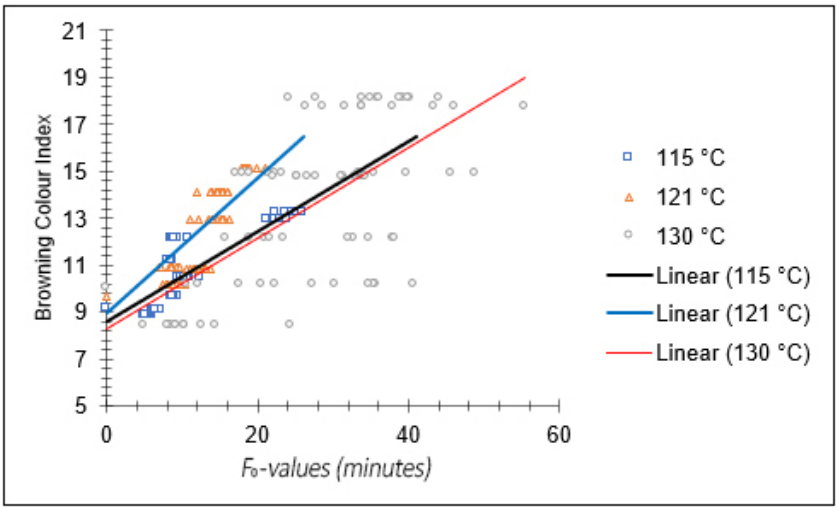

Figure 6: Effect of F_0-value at different retort temperatures (115, 121, and 130 ^{o}C) on the browning index of canned *A. bisporus* mushroom. The lines are lines of best fit.

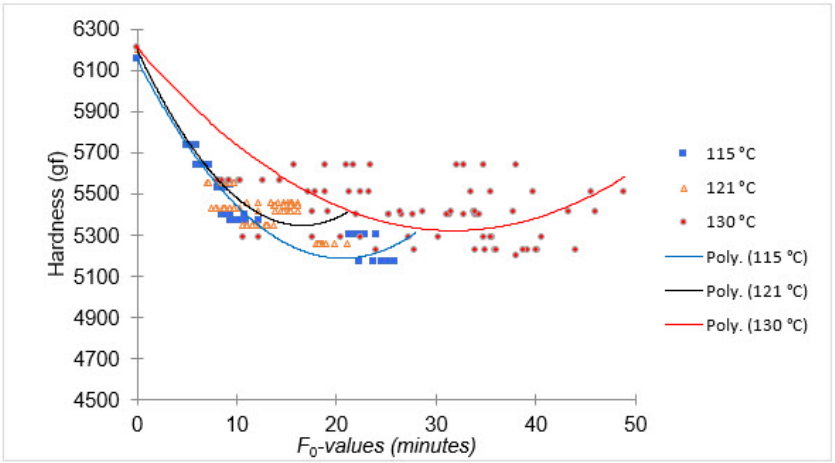

Figure 7: Effect of F_0-value at different retort temperatures (115, 121, and 130 ^{o}C) on the hardness (TPA) of canned *A. bisporus* mushroom. The lines are lines of best fit.

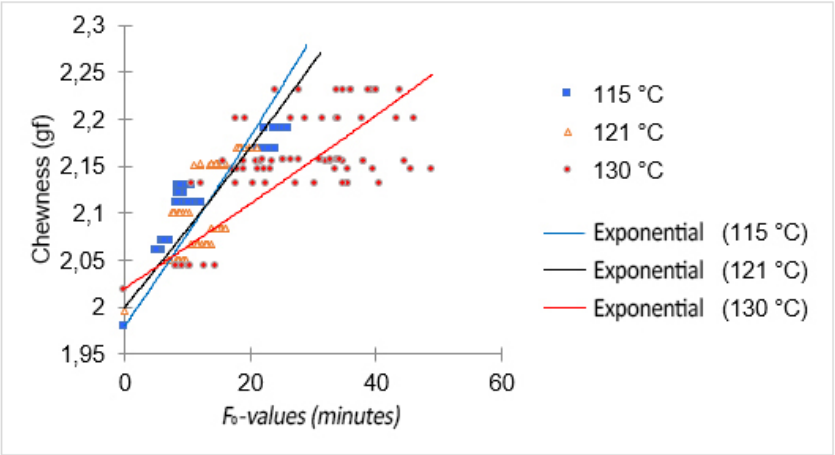

Figure 8: Effect of F_0-values at different retort temperatures (115, 121, and 130 ^{o}C) on the chewiness (TPA) of canned *A. bisporus* mushroom. Lines are lines of best fit.

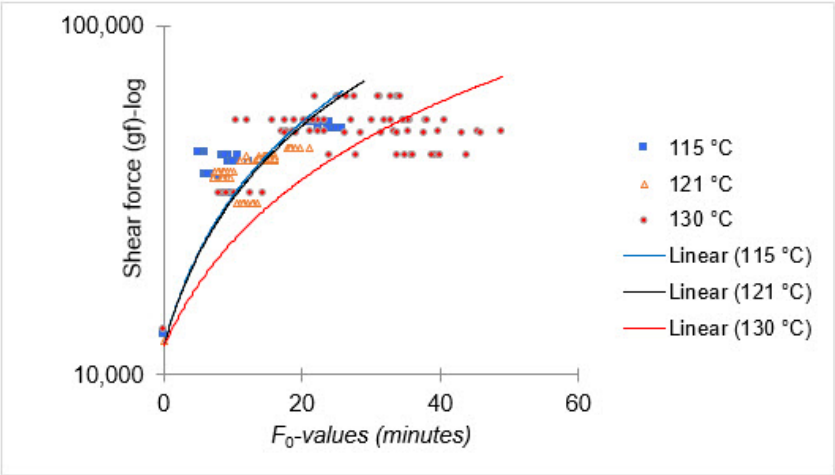

Figure 9: Effect of F_0-value at different retort temperatures (115, 121, and 130 ^{o}C) on the shear force of canned *A. bisporus* mushroom (Warner-Bratzler shear cell). The lines are lines of best fit.

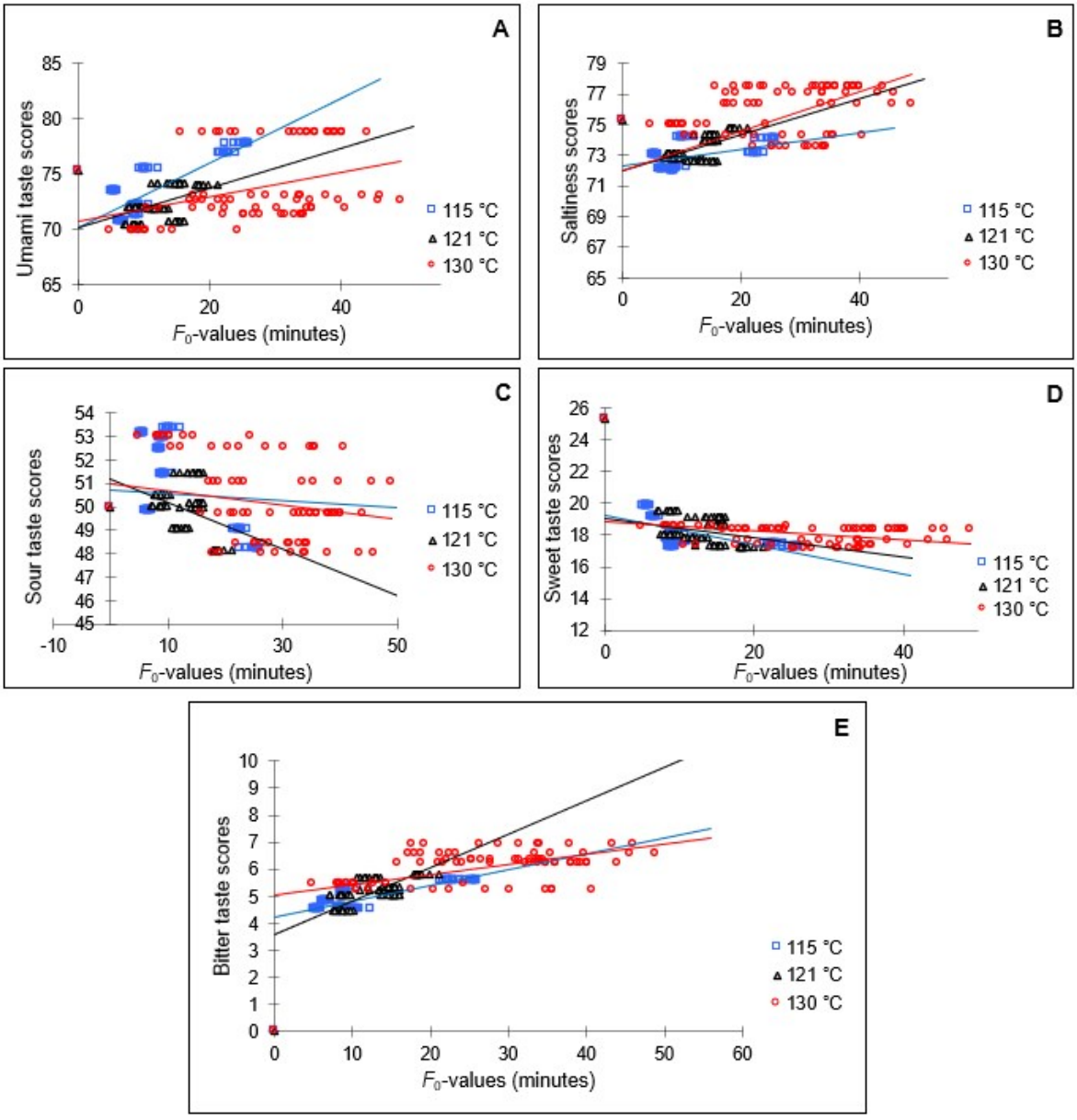

Figure 10: Effect of F_0-value at different retort temperatures (115, 121, and 130 °C) and on the taste intensity of canned *A. bisporus* mushroom (A=umami taste, B=saltiness, C=sour taste, D=sweet taste, E=bitter taste). The lines are lines of linear best fit

3.4 Sensory Attributes

Mushrooms have long been used as food or flavouring ingredients because of their unique and delicate taste (Chang & Wasser, 2012; Kurihara, 2009). Taste is an essential aspect for consumers in choosing mushroom products. Figures 10A-E show the effect of different F_0-values and retort temperatures (115, 121, and 130 ^{o}C) on the intensity of canned mushroom taste. At the same sterility value (F_0=10 minutes), regression analysis revealed that all the sensory attributes were significantly affected by the retort temperature.

Figure 10A shows that the umami score increases with increasing F_0-values for all retort temperatures. At the same F_0-value, the umami score of mushrooms processed at 130 ^{o}C was lower than the retort temperatures of 115 and 121 ^{o}C. The umami score of 130 ^{o}C was lower than other retort temperatures because to achieve the same F_0-value, a higher temperature (130 ^{o}C) needed less processing time compared with other retort temperatures (115 and 121 ^{o}C). The effect of sterility value and retort temperature on the umami taste intensity (Figure 10A) and the brown colour change (Figure 6) are interrelated. The increase of browning colour is probably due to the Maillard reaction during the sterilization process. More extended processing or retorting time has a more significant impact on the formation of umami taste as a result of the occurrence of non-enzymatic reactions during the sterilization process.

The increasing panellist scores also occured in salty taste (Figure 10B) and bitter taste (Figure 10E). The bitter and salty tastes increased as the F_0-value increased for all retort temperatures (Figure 10B and 10E). The rate of increase in saltiness score at 130 ^{o}C was higher than that at retort temperatures of 115 and 121 ^{o}C. As shown in Figure 10B, at the same F_0-value (10 minutes), the salty taste scores at retort temperatures of 115, 121, and 130 ^{o}C were 72.88, 73.17, and 73.28, respectively. Figure 10E demonstrated that the canning of mushroom at a retort temperature of 130 ^{o}C at a certain F_0-value, would result in the lowest bitter taste score compared to other retort temperatures (115 and 121 ^{o}C). The influence of non-enzymatic reactions may cause an increased bitter taste. The temperature of the retort significantly affected the intensity of the bitter taste. This phenomenon is in line with the change of BCI. As was described in Section 3.2., higher temperature shorter time resulted in less colour change. At the same F_0-value, the use of higher temperatures in the retorting process caused browning reactions to be much slower than the inactivation of *C. botulinum*. Slower browning reactions will produce fewer melanoidin or compounds which provide a lower bitter taste. Therefore, the temperature of 130 ^{o}C caused the taste of the mushrooms to be sweeter compared to the temperature of 121 and 115 ^{o}C. The z-value had a high value in the browning reaction, so the D-value did not decrease much when the process temperature was raised. The higher D-value indicated that the reaction rate was lower (D = 2,303/k). On the other hand, there was a slight decline in the sourness (Figure 10C) and sweetness (Figure 10D) with the increase in F_0-value for all retort temperatures. The decline of the sour taste at 115 ^{o}C was slower than that of other retort temperatures (121 and 130 ^{o}C). The sourness probably originated from the addition of ascorbic acid and citric acid to the mushroom media to improve or maintain the colour quality. Ascorbic acid is highly susceptible to losses during processing due to its solubility in water and because it is highly oxidizable (Chen & Ramaswamy, 2012). Figure 10D shows that sweetness scores tended to decrease with the increase in F_0-value for all retort temperatures. The rate of decline in the sweet taste at 115 ^{o}C was higher than that of the retort temperatures of 121 and 130 ^{o}C. It can be implied that, at the same sterility level, mushroom sterilization at higher retort temperature resulted in sweeter products. Generally, the sweet taste in mushroom products is favoured by consumers.

Overall, as the F_0-value rose, perceptions of umami, saltiness, and bitterness taste tended to intensify, and perceptions of sourness and sweetness tended to decrease at all retort temperatures. Commercial sterilization applications with a retort temperature of 130 ^{o}C indicate several sensory advantages, such as lower bitterness and higher sweetness compared to retort temperatures of 115 and 121 ^{o}C.

4 Conclusions

This study demonstrated that the canning process of *A. bisporus* mushroom at various F_0-values and different sterilization temperatures of 115, 121, and 130 ^{o}C resulted in changes in product quality and sensory attributes. Our findings showed that the canning process led to changes in the drained weight, colour, texture profile, and sensory attributes, which depended not only on F_0-value but also on retort temperature. At the same F_0-value (e.g., 10 minutes), we found that retorting the product at a higher temperature of 130 ^{o}C would provide benefits such as a lower browning rate, more sweetness, and also still provide an increase in the umami taste. Moreover, selecting the higher retort temperature (130 ^{o}C) also resulted in higher drained weight loss (0.99%), lower shear force, and lower BCI development. In addition, our findings showed the relationship between umami and browning colour trends, both of which are suspected to be linked to the Maillard reaction. The use of a higher temperature and shorter time is more favourable compared to that of lower temperature and longer time of retorting with respect to the physical and sensory properties.

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