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Preservation of Tilapia Fillet using Dried Lemongrass Leaves Pre-treatment and Closed System Dehydration Method

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Abstract

Tilapia fish is one of the important commercial aquaculture species, fast-growing, and a source of protein either on a wet or dry basis. An unpleasant smell associated with dried tilapia can make it challenging to market. For this purpose, lemongrass leaves with a strong citrus aroma and antimicrobial properties were used to pretreat the fish. This study aims to identify the best temperature and drying time for lemongrass leaves and the production of dried salted fillet tilapia to maintain quality and moisture. In this study, the mini dehydrator model Anywin FD-77 (closed system) was chosen as a drying tool. The dried lemongrass leaves were used as pre-treatment to remove the fishy smell by soaking fresh tilapia fillets and dried lemongrass leaves in water. The advantage of this combined method is that it is suitable for ensuring the hygiene of the dried fillet without outdoor weather constraints. Fresh tilapia fillets were smeared with edible salt and placed in a chiller for the curing process for 24 hours. The temperature of the drying condition was set up at different ranges between 40°C to 60°C, with a drying time duration of 24 to 48 hours. The moisture content of dried lemongrass leaves and dried salted fillet tilapia were analyzed using a moisture analyzer (Model AND MX-50). It was revealed in this study that drying lemongrass leaves with a mini dehydrator at 50°C for 15 hours provided the lowest moisture content of 7.40 %, which is the best to use for the pretreatment of the fish fillet. In the latter process, it was found that the best temperature and duration for drying salted fillet tilapia was 60°C for 36 hours with a final moisture content of 15.24 %. The electrical consumption of the mini dehydrator at this condition was reasonable (7.56 kWh/MYR1.6481). Using a mini dehydrator, the drying process of salted fillet tilapia can be accelerated, and the contamination can be prevented. This process has a high potential to be commercialized as it is easy to handle and can be multiplied on a larger scale.

Keywords Drying method, dehydrator, tilapia fillet, lemongrass leaves, closed system

1.0 INTRODUCTION

Tilapia contributes about 44.7% of freshwater aquaculture production (FAO, 2019). Tilapia is a commercially important aquaculture species that contains a fantastic source of protein and is low in saturated fat, calories, carbs, and salt (Moses et al., 2018). Tilapia has surpassed carp and salmon as the third most important fish in aquaculture, with global production exceeding 6.03 million metric tonnes in 2018 and increasing annually (Miao and Wang, 2020). Tilapia are among the easiest and most profitable fish to farm due to their manner of reproduction, tolerance of high stocking density, and quick growth. Dried tilapia is important to maintain the sustainability of tilapia production. Pre-treatment in dried fish preparation, including washing, is the critical and primary processing of fish to reduce the organic load and discharge. Characteristics of lemongrass leaves, such as powerful aroma (myrcene and limonene) and antibacterial components (citral and geraniol), can be an additive element during the washing process. The nutritional quality of raw lemongrass leaves cannot be maintained for an extended period, highlighting the need for the food industry to find a way to produce low-moisture lemongrass leaves and select a suitable preservation method (Saterah et al., 2023). The leaves of this plant cannot be stored as fresh for a long time and easily rotates over a long period. A study on lemongrass leaves' drying time and temperature was designed to produce the best drying method to preserve lemongrass leaves.

The primary goal of drying is to lengthen the product's shelf life, minimize packing requirements, and reduce transportation weight (Chibuzo et al., 2021). Sun drying is the common method (opened system) used to preserve agricultural products in tropical and sub-tropical countries (Patterson et al., 2018). Although this technique is cheap, salted fish are exposed and prone to insect attacks, fungal infections, and spoilt products due to rain, wind, moisture, and dust (Akwuobu et al., 2019). Sun-drying is labour-intensive, weather-depending, and time-consuming (Chabane and Adouane, 2018). Salting is one of the oldest and cheapest methods of preserving food, and it is done by using dry edible salt (Kumar, 2021). Most bacteria, fungi, and other potentially pathogenic organisms cannot survive in a highly salty environment due to the hypertonic nature of salt (Coly et al., 2020). Preserved food stayed healthy and fresh for days, avoiding bacterial decay (Deng et al., 2020).

A closed system convection drying using mini dehydrator technology offers an alternative way to process fresh products in clean, more hygienic, and sanitary conditions with minimum energy costs. The mini food dehydrator is convenient and can be handled with low energy consumption. The constant temperature in indoor drying might reduce nutrient degradation by minimizing lipid oxidation and protein denaturation (Haque and Adhikari, 2015). Compared to open sun drying, the temperature was lowest during the darkness and highest during the day, which affected the consistency of the quality of the open sun-dried products. Modern technology, such as applying a closed system mini dehydrator, is inevitable in adding value and ensuring food safety in the salted fish industry. Using mini dehydrators for dried fish products is still not common and yet applicable for income generation projects for the community, either for small or medium-scale industries. In establishing the processing steps, finding the best conditions for the drying and pretreatment process to produce high-quality and rich-nutrient dried fish products is important. Hence, this study was aimed to determine i) the optimum temperature and time of the drying process, ii) the electrical consumption of a closed system for the production of dried lemongrass and dried salted tilapia, and iii) the effectiveness of lemongrass toward quality (mold and yeast) of dried salted tilapia after pre-treatment.

2.0 MATERIALS AND METHODS

2.1 Study on drying time and temperature of lemongrass leaves

Fresh lemongrass leaves at the complete maturity stage were collected from a research farm UTM- Campus Pagoh. Fresh green leaves were selected on this basis. The leaves were washed with clean water and cut into small pieces at uniform sizes (2 cm to 3 cm long) with clean stainless-steel scissors (Saterah et al., 2023). Fresh-cut lemongrass leaves were prepared into 15 samples weighing 200 g. 200 g of cut-green lemongrass leaves were dried using a mini dehydrator (Model Anywin FD-770) at nine different times: 1, 2, 3, 4, 5, 6, 7, 8, and 9 hours at a constant temperature of 35°C. The other six samples of cut-lemongrass leaves were dried at different temperatures, 35, 40, 45, 50, 55, and 60°C at a constant 15 hours of drying period. The moisture analyzer (Model ANK MX-50) was pre-heated at 105°C for 2 to 3 min. 2 g of dried lemongrass leaves were cut into small pieces and placed into the analyzer. Samples 1 to 15 were analyzed, and moisture content (%) was obtained.

2.2 Study on production of dried salted tilapia

The fish samples were collected in the pond from the research farm UTM-Pagoh Campus. The fish was cut into fillets by removing scales, heads, and bones. The dried lemongrass leaves were used as pre-treatment to remove the fishy smell by soaking fresh tilapia fillet and lemongrass leaves in tap water for 3 to 5 min. Fresh tilapia fillets were smeared with 10 % edible salt and placed in a chiller for 24 hours for the curing process, as proposed by Luiz-Alonso et al. (2021). After 24 hours of the curing process, excess water was drained out. Salted fillet tilapia was placed in a mini dehydrator. The temperature of the mini dehydrator was set in different ranges within 40, 50, and 60°C, with drying time duration of 24, 36, and 48 hours. Dried salted fillet tilapia was analyzed for moisture content using the moisture analyzer (Model AND MX-50) at 105°C. Dried salted fillet tilapia was ground into powder. The aluminum weighing boat was put in a desiccator to ensure no moisture would affect the reading. 2 g of the sample was weighed, flattened, and scattered on the weighing boat to ensure uniform drying. In two different storage periods and drying times (7 days, 36 hours, and 7 months, 48 hours), dried salted fillet tilapia samples were analyzed for mold count. Potato dextrose agar was prepared, and the pH condition was adjusted to neutral by adding 5 N NaOH. A 1 g sample of dried salted fish was collected in sterile conditions and homogenized in 9 mL of peptone water solution. After preparing a series of dilutions to 10-6, 1mL of each dilution was poured into the empty plate, and nutrient agar was added. Plates were inverted and incubated at 25±1°C for 5 days. Colony growth is calculated and recorded in colony-forming units per gram (CFU/g) (Arifan et al., 2019).

2.3 Data analysis

The moisture content was evaluated using the analysis of variance (ANOVA) procedures of the Statistical Packages for Social Sciences (SPSS) version 16. Means comparisons between treatments were performed by Tukey test at $p<0.05$. The cost of electricity consumption for drying lemongrass leaves and dried tilapia using a mini dehydrator was calculated following the domestic rate at first 200 kWh, which is MYR 0.218.

3.0 RESULTS AND DISCUSSION

3.1 Drying time selection of lemongrass leaves

Table 1 shows the drying time of lemongrass leaves from 1 h to 9 h at a constant temperature of 35°C. The moisture content range for all samples was from 31.06 ± 0.24 % (S9) to 65.16 ± 0.71 % (S1). The moisture content of all samples was significantly ($p<0.05$) reduced when drying time increased. To extend the shelf life of dried lemongrass leaves, the moisture content is recommended from 3 % - 12 % (Mabai et al., 2018). Drying times from 1 hour (S1) to 9 hours (S9) with a constant drying temperature of 35°C were unsuitable because the moisture content was out of the recommended range.

Table 1 Moisture of dried lemongrass leaves at drying time (1 -9 hours, h).

Sample	Drying time (h)	Temperature (°C)	Moisture Content (%)
S1	1	35	65.16 ± 0.71^{a}
S2	2	35	63.17 ± 0.45^{a}
S3	3	35	51.13 ± 1.08^{c}
S4	4	35	56.52 ± 0.26^{b}
S5	5	35	47.33 ± 1.31^{d}
S6	6	35	36.66 ± 0.63^{e}
S7	7	35	50.64 ± 1.53^{cd}
S8	8	35	38.65 ± 0.18^{e}
S9	9	35	31.06 ± 0.24^{f}

Note: Mean ± S.D in the same column with different superscripts represents a significant difference ($p<0.05$)

3.2 Drying temperature selection of lemongrass leaves

The initial moisture content in the freshly harvested lemongrass leaves sample was 71.09 %. This finding is similar to other research by Mabai et al. (2018), where the initial moisture content in freshly harvested lemongrass leaves samples was 73 %. Table 2 shows the moisture content of dried lemon grass leaves at drying temperatures of 35°C to 60°C. The moisture content of all samples was significantly ($p<0.05$) reduced when the drying temperature increased. The moisture content of S12 (11.58 ± 0.18 %), S13 (7.40 ± 0.18 %), S14 (7.18 ± 0.04 %), and S15 (6.57 ± 0.03 %) with a drying temperature of 45°C to 60°C were within the recommended range (Mabai et al., 2018). The food product's stability and shelf life depend on the moisture content (Qiu et al., 2019).

Table 2 Moisture of dried lemongrass leaves at drying temperature (35 to 60°C).

Sample	Drying Time (h)	Temperature (°C)	Moisture Content (%)
S10	15	35	25.60 ± 0.25^{a}
S11	15	40	12.73 ± 0.15^{b}
S12	15	45	11.58 ± 0.18^{c}
S13	15	50	7.40 ± 0.18^{d}
S14	15	55	7.18 ± 0.04^{de}
S15	15	60	6.57 ± 0.03^{e}

Note: Mean ± S.D in the same column with different superscripts represents a significant difference (p<0.05)

The suitable temperature conditions of dried lemongrass leaves were S12 (45°C), S13 (50°C), S14 (55°C), and S15 (60°C). The best one was selected as a pre-treatment to wash fish fillets. Considering the suitable moisture content, appropriate drying time, and the least cost of electricity consumption, S13 dried lemongrass was ideal for preparing dried lemongrass. With a temperature of 50ºC and at the same drying time, which is 15 hours, the moisture content of lemongrass was below 10%. The moisture content of lemongrass below 10% is important to avoid fungus cultivation during storage or packaging (Osibona et al., 2018). Moisture content A properly dried lemongrass leaf has a strong citrus smell that helps reduce the odour of fish fillets.

3.3 Electricity consumption at different drying temperatures of lemongrass leaves

Table 3 shows that electricity consumption increased when the drying temperature increased. The most effective drying temperature for lemongrass leaves was 50°C. The electricity usage at this temperature for 15 hours of drying time is the minimum for (MYR 0.5723) domestic usage. The moisture content of dried lemongrass at 50°C was 7.40%, within the recommended moisture content range. Drying temperatures at 55°C and 60°C was not recommended because electricity consumption was higher and costly. The higher drying temperatures would affect the active ingredients of lemongrass leaves (Tran et al., 2018).

Table 3 Cost of electricity consumption of drying lemongrass leaves using one unit of mini dehydrator.

Drying Temperature (°C)	Energy (kWh)	Cost of Electricity Consumption (MYR)
		Domestic Usage
35	1.8375	0.4006
40	2.1000	0.4578
45	2.3625	0.5150
50	2.6250	0.5723
55	2.8875	0.6295
60	3.1500	0.6867

3.4 Drying temperature and time selection on tilapia fillet

Table 4 shows the weight loss percentage of salted fillet tilapia after the drying process. The higher the rate of weight loss, the lower the moisture content in the dried salted tilapia fillet. The weight loss percentage of salted tilapia after drying was significantly increased when the drying temperature increased. The weight loss percentage in tilapia fillets ranged from 25 % to 71.5 %. It was suggested that the best condition for drying tilapia was at 60ºC with a drying duration of 36 hours. At this drying condition, the moisture content of dried tilapia fish was 15.24 %, which was within the recommended range (10-20 %) (Cao et al., 2021). The drying temperature of fish above 60ºC can avoid microbial risk in the product (Opara et al., 2019). The result is promising, as the moisture level below 20 % was not suitable for the growth of bacteria, as suggested by Mansur et al. (2013). This result is also comparable to a study by Chukwu (2009), which used an electric oven to dry at 110°C for 45 minutes, resulting in 17.13 % moisture content. This study can also be compared to one conducted by Flowra et al. (2012). A range of 14.06 % to 24.58 % of moisture content was found in five dried fish samples of striped dwarf catfish (*Mystus vittatus*), snakehead fish (*Channa punctatus*), elongate glassy perch let fish (*Chanda nama*), Ganges River Sprat (*Corica soborna*) and Beltfish (*Trichuirus haumela*). The drying temperature of sample S9 at 60 °C with 48 hours of drying time is not recommended because the moisture content is below the recommended range (7.78 %). The time consumption for tilapia fillet dried was 48 hours longer than that of sample S6, which was 36 hours. The longer drying time would affect the production cost of dried salted fillet tilapia.

Table 4 Percentage of weight loss (%) of salted fillet tilapia after drying.

Sample	Drying Time (h)	Drying Temperature (ºC)	Moisture Content (%)	Percentage of Weight Loss (%)
S1	24	40	40.3	25.0
S2	24	50	35.5	30.0
S3	24	60	29.0	35.0
S4	36	40	23.3	31.0
S5	36	50	18.4	38.0
S6	36	60	15.24	54.0
S7	48	40	9.88	58.0
S8	48	50	8.83	65.0
S9	48	60	7.78	71.5

3.5 Electricity consumption at different drying conditions of salted fillet tilapia

Table 5 shows the energy usage and cost of electricity consumption of a mini dehydrator to produce one cycle of dried salted fillet tilapia. Electricity consumption increased when the drying temperature increased for domestic and commercial usage. The best condition of drying temperature (60°C with 36 hours of drying time) showed 7.56 kWh of energy for domestic usage (MYR 1.65). Drying temperature at 60°C with 48 hours drying time was not recommended due to higher and costly electricity consumption.

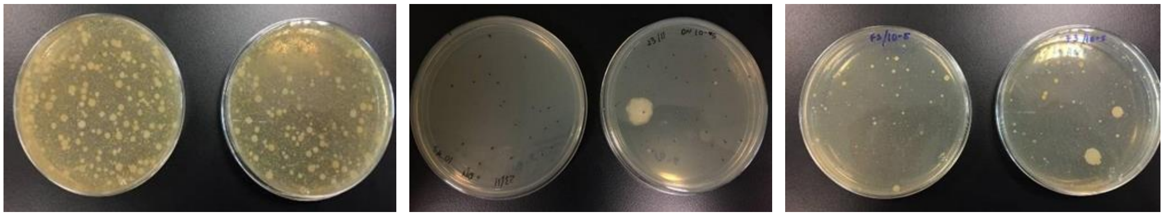
Table 5: Energy usage and electricity consumption cost of one mini dehydrator unit.

Sample	Drying Temperature(°C)	Drying Time (h)	Energy (kWh)	Electricity Cost (RM)
S1	40	24	3.36	1.4616
S2	50	24	4.20	1.8270
S3	60	24	5.04	2.1924
S4	40	36	5.04	2.1924
S5	50	36	6.30	2.7405
S6	60	36	7.56	3.2886
S7	40	48	6.72	2.9232
S8	50	48	8.40	3.6540
S9	60	48	10.08	4.3848

3.6 Total mold count (TMC)

According to Fifteenth Schedule Regulation 39 in Malaysia 1985 Food regulation, fish and fish products ready for consumption should have a total plate count of less than 106 CFU/g at 37°C for 48 hours (Philip, 2015). In Malaysia, the current law and regulation for the standard necessary permit of a salting processed product to be considered suitable for human consumption has not yet been established. Sri Lanka Standard Institute stated that dried fish that humans can consume must have mold and yeast count lower than 10^3 CFU/g (<10^3) after a 6-month storage period (Ginigaddarage et al., 2018). Under the Technical Regulation on Good Practices and Food Services in Brazil, the amount of allowed mold and yeast in shrimp-dried processed food was lower than 10^4 CFU/g for food (Freitas et al., 2020).

Figure 1 and Table 6 show the TMC of dried salted fillet tilapia at different storage periods and drying times. Both storage times have resulted in low values of mold and yeast count. Figure 1 and Table 6 can conclude that the effect of the pre-treatment with lemongrass is significant to the amount of TMC. It is apparent from Figure 1 that the high amount of mold and yeast are significantly visible and scattered in sample (a) compared to pretreated samples (b) and (c). The amount of TMC for 7 days and pro-long to the 7 months duration is still low in numbers of CFU, which is an advantage. This indicated that the salted fish would not be contaminated with mold and yeast during storage activities. This could be due to the antimicrobial properties that can be inhibited by the lemongrass' bioactive compound.



(a) (b) (c)

Figure 1 Example of mold and yeast results on plate agar: (a) Without pre-treatment with lemongrass, (b) After 7 days pre-treatment with lemongrass, and (c) After 7 months pre-treatment with lemongrass.

Table 6 Total Mold Count (TMC) in dried salted fillet tilapia.

Storage period	Drying temperature (°C)	Drying time (h)	Moisture content (%)	Mold and Yeast count (CFU/g)
7 months	60	36	15.24	1.3×10^3
7 days	60	48	7.78	5.0×10^1

4.0 CONCLUSION

In conclusion, this study suggested that the drying condition of the mini dehydrator (closed system) at 50°C for 15 hours was the most suitable for lemongrass leaves where the moisture content is 7.40 %, which is within the recommended range (3-12 %). Electrical consumption was reasonable (2.6250 kWh/MYR 0.57). This study also suggested that the drying condition of the mini dehydrator (closed system) at 60°C for 36 h was the most suitable condition for salted fillet tilapia fish where the moisture content is 15.24 %, which is within the recommended range (10-20 %). Electrical consumption was reasonable (7.56 kWh/MYR 1.65). Combining lemongrass pretreatment and salting the fish fillet using a mini dehydrator as a drying tool has great potential to be commercialized for high-quality dried fish products.

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References

Akwuobu, C. A., Antiev, W. S., & Ofukwu, R. A. P. (2019). Fungal contaminants of smoke-dried fish sold in open markets in Makurdi, Benue state, north-central Nigeria. Food and Nutrition Sciences, 10(3), 290-297.

Arifan F., Winarni S., Wahyuningsih I. P., & Broto R. W. (2019). Total Plate Count (TPC) Analysis of processed ginger on Tlogowungu tourism village, Advances in Engineering Research, 167, 377-379.

Cao, J., Feng, A., He, Y., Wang, J., Liu, Z., Xia, G., Lin, X., Shen, X., Zhou, D. & Li, C. (2022). The effect and mechanism of four drying methods on the quality of tilapia fillet products. *Food Frontiers*, *3*(2), 316–327.

Chabane F., Adouane F. (2018). Experimental investigation of the solar drying & solar collector design for drying agriculture product (Mint), Chemical Engineering Transactions, 71, 1387-1392

Chibuzo, N. S., Osinachi, U. F., James, M. T., Chigozie, O. F., Dereje, B., & Irene, C. E. (2021). Technological advancements in the drying of fruits and vegetables: A review. African Journal of Food Science, 15(12), 367–379.

Chukwu, O. (2009). Influences of drying methods on nutritional properties of tilapia fish (*Oreochromis nilotieus*). World Journal of Agricultural Sciences, 5(2), 256–258.

Coly M. L., Gueye M. S., Mbaye B., Faye W., & Diamanka A. (2020). Fish pre-treatment with salt brine; Process study and drying kinetics, International Journal of Advanced Research, 8(10), 35-44.

Deng Y., Wang R., Wang Y., Sun L., Tao S., Li X., Gooneratne R., & Zhao J. (2020). Diversity and succession of microbial communities and chemical analysis in dried *Lutianus erythropterus* during storage, International Journal of Food Microbiology, 314 (1008416), 1–10.

FAO 2019, Food and Agriculture Organization www.fao.org/fishery/facp/mys/en accessed 04.04.2023

Flowra, F. A., Nahar D. G., Tumpa A. S., & Islam M. T. (2012). Biochemical Analysis of Five Species of Bangladesh, University Jornal of Zoology, Rajsashi University, 31, 9-11.

Freitas J. D, Pereira Neto L. M., Silva T. I. B. D, Oliveira T. F. L. D., Rocha J. H. L. D, Souza M. D., Marchi P. G. F. D, & Araujo A. V. D. (2020). Counting and identification of molds and yeasts in dirty salted shrimp commercialized in Rio Branco, Acre, Brazil, Food Science and Technology, 41(1), 284-289.

Ginigaddarage, P. H., Surendra, I. H. W., Weththewa, W. K. S. R., Ariyawansa, K. W. S., Arachchi, G. G., Jinadasa, B. K. K. K., Hettiarachchi, K. S. & Edirisinghe, E. M. (2018). Microbial and chemical quality of selected dried fish varieties available in Sri Lankan market. Sri Lanka Journal of Aquatic Sciences, 23(1), 119–126.

Haque M. A., Adhikari B. (2015). Drying and denaturation of proteins in the spray drying process, Handbook of Industrial Drying, 33(10), 971-985.

Kumar K. S. (2021). Salt curing, smoking and drying of fishery products Chapter In: C.O. Moha, K. Elavarasan, S. Sreejith, K.R. Sreelakshmi, (Eds). Fish and Marine Products Processing, Central Institute of Fisheries Technology, Cochin, India, 73–89.

Luiz-Alonso S. A., Girón-Hernández L. J., López-Vargas J. H., Muñoz-Ramírez A. P. & Simal-Gandara J. (2021). Optimizing salting and smoking conditions for the production and preservation of smoked-flavoured tilapia fillets. Food Science and Technology, 138 (110733), 1-7

Mabai P., Omolala A., Jideani A. (2018). Effect of drying on quality and sensory attributes of lemongrass (*Cympogon citrus*) tea, Journal of Food Research, 7(2), 68-76.

Mansur, M. A., Rahman, S., Khan, M. N. A., Reza, M. S., & Uga, S. (2013). Study on the quality and safety aspect of three sun-dried fish. African Journal of Agricultural Research, 8(41), 5149-5155.

Miao, W., & Wang, W. E. I. W. E. I. (2020). Trends of aquaculture production and trade: Carp, tilapia, and shrimp. Asian Fisheries Science, 33(S1), 1-10.

Opara, U. L., Caleb, O. J., & Belay, Z. A. (2019). Modified atmosphere packaging for food preservation. Food Quality and Shelf Life, 235-259.

Osibona, A. O., Ogunyebi, O. O., & Samuel, T. O. (2018). Storage fungi and mycotoxins associated with stored smoked Catfish (Clarias gariepinus). Journal of Applied Sciences and Environmental Management, 22(5), 643-646.

Patterson, J., Kailasam, S., Giftson, H., Immaculate, J. K. (2018). Effect of drying technologies on the biochemical properties of *Stolephorus commersonnii*, Food Quality and Safety, 3, 153–158.

Philip, A. (2015). Food Safety in Malaysia. Symposium Ensuring Food Safety: An Important Challenge Today. The 30th CMAAO General Assembly & 51st Council Meeting, 58(4).

Qiu, L., Zhanga, M., Tang, J., Adhikari, B., & Cao P. (2019). Innovative technologies for producing and preserving intermediate moisture foods: A review. Food Research International, 116, 90-102.

Saterah, R., Mohammadi-Ghermezgoli, K., Ghaffari-Setoubadi, H, & Alizadeh-Salteh, S. (2023). The effectiveness of hot-air, infrared drying techniques for lemongrass: appearance acceptability, essential oil yield, and volatile compound preservation. Scientific Report, 13, 18820.

Tran, T. T., & Nguyen, H. V. (2018). Effects of spray-drying temperatures and carriers on physical and antioxidant properties of lemongrass leaf extract powder. Beverages, 4(4), 84.