

Microbiological Evaluations of 'Foods Companion' Prepared from the Waste-Peels of Fresh Tomato Fruits (*Solanum lycopersicum*) and Three Fresh Vegetables

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Abstract

The aim of this study is to establish the microbiological status of 'foods companion' prepared from the food loss and waste including peels of processed fresh tomato fruits, wastes (Tomato concentrate) generated from the tomato paste factory, fresh hot pepper, fresh sweet pepper, and fresh onion, spiced with fresh garlic and fresh ginger. In this study, after successfully developing samples of 'Foods Companion' the microbial analysis results of log₁₀cfu⁻⁸ (i.e. less than 10 cells count) revealed that the HACCP plan and hurdle technology employed were effective because the microbial loads fall within the microbiological limits required for ready to eat foods (RTEs). Hence, the microbial load results of less than 10 cells counts indicating the impact of HACCP plan adopted and the hurdle technology used for the preparation of 'foods companion'. Hence, results of microbial analyses predict that the foods companion samples are microbiologically safe for human use and consumption.

Keywords: Foods Companion; Food Supply Chain; Food Waste; Food Loss; HACCP

Introduction to Study

The principal focus of this study is to convert fresh tomato waste/loss to a safe ingredient called the 'foods companion'. And foods companion is a product of processed peels of fresh tomato fruits, fresh sweet pepper, fresh hot pepper, fresh onions, potable water and salt. Food loss and waste (FLW) has become an important topic of discussion among the academia, Captains of foods manufacturing industries and the general public due to its high social and economic costs and its relationship to waste management and climate change challenges; and also FLW is one of the several major problems threatening sustainable food and environmental security. And for the sake of clarity there is the need to vividly present 'food losses and 'food waste'. Food losses has been defined as the decrease in edible food mass throughout the part of the food supply chain that specifically leads to edible food for human consumption; while on the other hand, food waste is the removal of food fit for human consumption by negligence or choice that is positive; and also food waste occurs at the retail and final consumption because it relates to the behaviour of retailers and consumers [19,20]. In addition, food losses is

understood as accidentally occurring for reasons not under the control of persons concerned due to several factors including ignorance, lack of skills, inadequate technology, poor logistics and infrastructure; while food waste has been characterized by an element of intended and/or unintended human behaviour that could lead to food removal from the food supply chain for another use other than for human consumption [8]. Also, it has been established that FLW leads to huge economic losses and it contributes to environmental dilapidation [8]. And food losses and waste are the masses of food lost or wasted in the part of food supply chains leading to edible food products going to human consumption; and for that foods that are originally meant for human consumption but which by chance gets out of the human food chain is regarded as food loss or food waste even if it is then directed to a non-food use, such as animal feed and bioenergy [9]. However, FLW is an issue that is morally related owing to the fact that about twelve percent (12%) of the world's population is facing the threat of hunger [6,8]. But despite this glaring facts and awareness, FLW remains excessively high despite several human efforts to avert it [6].

Definitions of food loss and food waste

In 2017 the FAO defines food losses and wastes as a decrease in quality and/or quantity of food or the combination of both the quality and quantity, respectively. In other words, food losses and wastes is a reduction in the foods availability; a decline in the nutritional and/or economic value of food, and/or a deterioration in food safety [8]. Another author defined Food losses occur in the food supply chain at the point of food supply chain at the point of handling such as the harvesting, transportation, and preparation leading to post-harvest losses [19]; while on the day hand, food losses occur in the food supply chain, but, food waste is a sort of food losses due to human action and/or inaction because some actions taken by human leads to wastage of food [14].

Furthermore, food waste results from the discarding or alternative (i.e. non-food) use of safe and nutritious food for human consumption all along the food supply chain (FSC) [8,9]. However, food losses occur accidentally, while food waste has been characterized by an element of intended or unintended behaviour of a man [19]. Although, in the developing nations such as Nigeria, the key-drivers in the generation of waste include the lacking of infrastructure and associated technical and managerial skills in food production and post-harvest food processing [19,22,23].

Estimation of world's global record of food loss and food waste

Over one third (i.e. 1/3) of global food supply (GFS) for human consumption is lost or wasted leading to huge greenhouse gas emission caused by the production of foods that get lost or wasted along the FSC [8,9,23]. It is has been established before and presently that foods are lost or wasted throughout the FSC; but significant losses take place in the food processing industries at the stage of food handling and preparation especially in the developing nations that live on the margin of food insecurity; and it is believe that a reduction in food losses could impact positively and immediately on their livelihood [8,9]. And from the global perspective on FLW, on annual basis about 1.3 billion tonnes of food is generated as waste and in an economic perspective this cost roughly 750 billion US dollar [8,9]. And it has been well established by several reports that in the industrialized nations and developing countries over 40% of the food losses occur at the stage of post-harvest and preparation; and as well at the retail and consumers levels, respectively [8,9,23].

Annual loss and waste recorded for fruits and vegetables

The fruits and vegetables dominate the rate of food losses among the food commodity accounting for about 15 - 30% and several studies and reviews have reported similar trends around the World [15,19-23]. And in most cases, losses of fruits and vegetables is due to post-harvest losses caused by several factors including poor harvesting practice, poor handling processes, and unnecessary quality standards set by retailers for grading this class of food commodity that has high perishability [8,9,15,16]. The estimated loss/waste for fruits and vegetables on annual basis around the globe due to several factors highlighted above is quite alarming (Table 1).

Agricultural Production	Post-harvest Handling and Storage	Processing and Packaging	Distribution	Consumption
10%	09%	25%	17%	05%

Table 1: Estimated wastes percentage for fruits and vegetables in each step of the food supply chain in Sub-Saharan Africa nations.

Source: [9,18].

Table 1 above presents the various estimated percentages of losses and wastages for fruits and vegetables based on specific operation and practices; and during processing and distribution more losses and wastages are recorded compared to the stages of production and post-harvest handling and storage; while consumption stage recorded the least loss and waste [16,18,23].

Clearly and without an iota of doubts, at the point of processing and packaging a higher loss and waste is recorded (25%); this is owing to the fact that substantial percentage of the loss and waste comes from the ‘discards’ such as the trimmings, spoils, peels, and seeds that are not used at the point of preparation and packaging [16,18,23]. For example, during the fresh Tomato fruits crushing between the years 2021 to 2023, ALDUSAR Tomato paste production plant generated wastes that run to Hundreds of Thousands of Tonnes from those Tomato fruits graded as spoiled, trimmings generated during sorting and pre-washing handling and peels generated after crushing. And all the times the loss/waste generated are usually sundried, packaged in sacks and kept in store as animal feeds as the best option to reduce the loss/waste of the factory [16]. And it has been in record that in the Sub-Saharan African nations, such as Nigeria, on annual basis less than 100 million tonnes of fruits and vegetables are produced for human uses and consumption [8,9,15,16].

Nonetheless, a closer understanding of the literature reveals that the issue of loses and wastage of food in food supply chains is complex and it requires attention from various stakeholders including farmers, policymakers, managers of industries and society [5,6]. However, it has been reported that both the public and private sectors in developing nations should strengthen the food supply chains by investing adequately in food processing and packaging industries for the singular purpose of curbing food losses and wastages and this is owing to the fact that food security is a great concern in most parts of the developing countries and food production must increase significantly to meet the present and future demands of an increasing population [9]. Also, efforts are ongoing because FAO is working on a global food loss index indicator, which uses the caloric content of food as a common unit of measure for the assessment of progress in reducing food losses and wastages through policies, programmes and projects have been launched including global public-private partnerships, such as the global initiative on food loss and waste reduction popularly called save food initiative [8]. And of recent the strong focus to reduce FLW has increased tremendously and the central focus for embarking on this laudable research to develop a safe foods companion from the FLW generated in ALDUSAR, Foods and Beverages Limited, Katsina, Katsina state, Nigeria [16].

Furthermore, some researchers have tried to develop a model on how food loss and waste can tackled in the society (Figure 1). And in this M-Model based research framework below all stakeholders including players, pointers and drivers are expected to partake in mitigating food loss and waste in the food supply chain.

Introduction to background of study

Fresh tomato fruits processing factories generated various and a huge amount of wastes at the points of primary processing (primary sorting, washing, disinfecting and secondary sorting before crushing operation begins) and at the points of crushing and concentrating, respectively. Hence, these wastes that are generated translated to a huge loss of money by the factories and therefore there is the need to reprocess and transform these wastes into a functional product that will save and curb the economic loss experienced by the fresh tomato fruits factories and as well generate additional income to the fresh tomato fruits processing factories such as the ALDUSAR food and beverages limited.

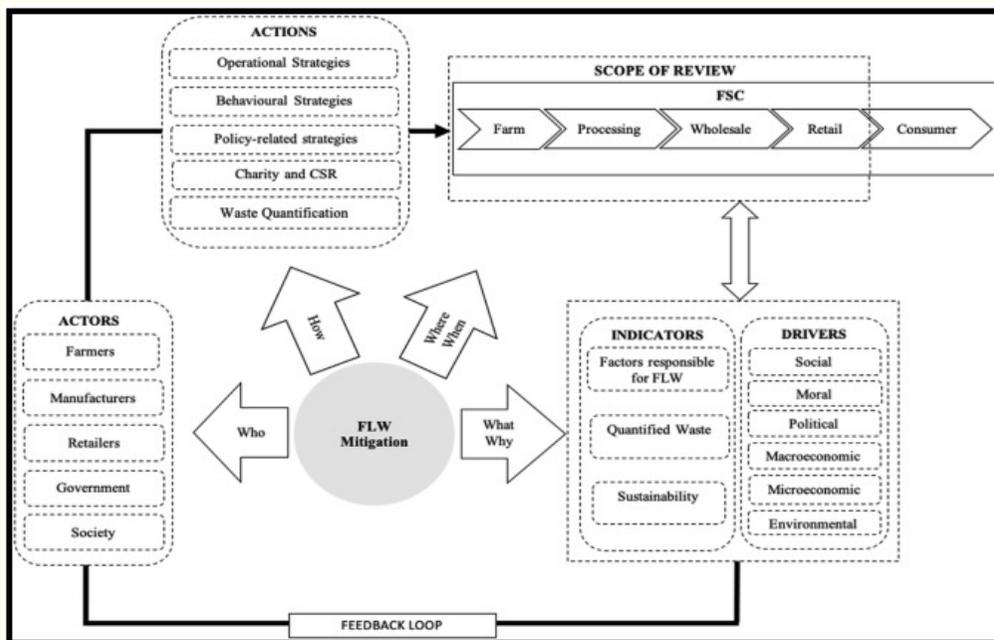


Figure 1: Food loss and waste mitigation model (M model) [6].

ALDUSAR food and beverages limited was established in 2014 and commissioned in 2017 as a fresh tomato fruits processing factory; and it generates various and a huge amount of wastes at various points of primary processing. Hence, these wastes that are generated translated to a huge loss of money by this factory and therefore there is the need to reprocess and transform these wastes into a functional product “foods companion” that will save and curb the economic loss experienced by the fresh tomato fruits factories and as well generate additional income to the FTFs processing factories [16].

In the ALDUSAR fresh tomato fruits processing factory the major wastes generated can be classified into three (Figure 2) the avoidable, possibly avoidable and unavoidable and these include peels of crushed tomato fruits, splinters of tomato paste and other fresh tomato fruits that are unfit for further processing and inclusion into the tomato paste [16].

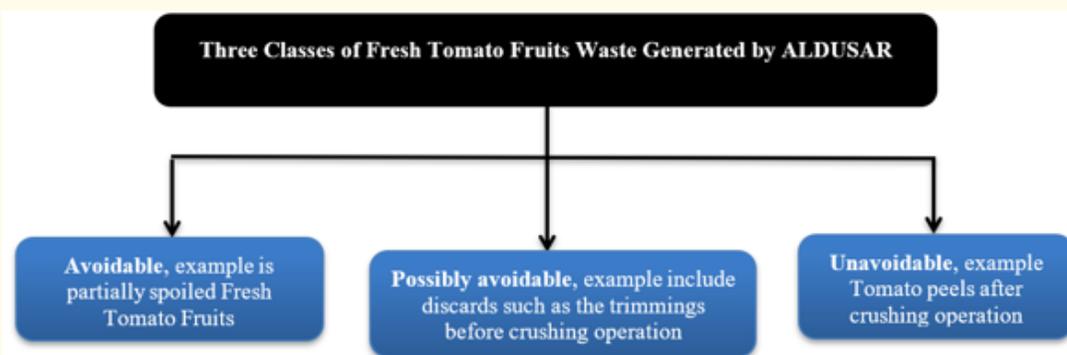


Figure 2: Three classes of wastes generated by the ALDUSAR foods and beverages Ltd.

Source: [1-3,16,18].

Figure 2 present the three types of wastes generated before and after crushing operations on yearly basis. The avoidable waste generated is achievable if a certified supply is used for the supply of wholesome fresh tomato fruits as duly guided and recommended by the consulting firm in the HACCP plan record for fresh tomato supply to the factory. While the possibly avoidable waste generated can be made possible if the first step of supplying principle and rules are strictly adhered to by the management of ALDUSAR. While unavoidable waste generated (i.e. peels of crushed tomato fruits) is always a constant waste generated as far as FTFs crushing is commenced in the fresh tomato fruits processing industries owing to the fact that it is only when the peels are separated from the flesh that a paste can be prepared from the fresh tomato fruits. And the peels are collected and dried (Plate 1) as animals feed usually for cattle goats and sheep consumption. However, the estimated wastes generated by the ALDUSAR (Table 2) are as presented below.



Plate 1: Sundried spent fresh tomato peels after crushing operation [16].

Plate 1 presents unpacked dried peels of FTFs crushed for the preparation of tomato paste used as animals feed by the ALDUSAR, owing to the fact the owner of company rears animals such as cattle, camels, sheep and goats [16].

Estimates of wastes generated by the ALDUSAR for three years (2021-2023)

ALDUSAR being a fresh tomato fruit processing company experiences loss and generates several hundred thousands of tonnes of vegetable loss and wastes (VLWs) from their supplies. And these VLWs translate to losing substantial amounts of fund of the factory. Hence, the need to employ a modern processing technology that is safe to convert this waste to wealth in order to reduce economic loss and prevent environmental degradation due to the emission of gases from the VWs that are not needed in the environment by living things [1-3,16].

Year	FTFs Supplied (Kg)	Spoils (Rejects) (Kg)	Discards (Trimming) (Kg)	Crushed FTFs (Kg)	Peels (Dried) (Kg)	Estimated VLWs (Kg)	Difference %	Remarks on Annual VLWs Generated
2021	169,245.50	3,233.00	2,432.00	155,452.00	8,128.50	13,793.50	8.20	High
2022	897,387.70	12,000.00	4,825.23	867,212.75	13,349.72	30,174.95	3.40	Lowest
2023	1,164,775.70	107,914.60	4,616.00	1,056,861.10	406,396.00	518,926.60	44.60	Highest
Grand Total	2,231,408.90	123,147.60	11,873.23	2,079,525.85	427,874.22	562,895.05		

Table 2: Estimated VLWs generated by ALDUSAR foods and beverages limited (2021-2023).

Source: [1-3,16].

Table 2 present the estimated VLWs generated by ALDUSAR from the supplied fresh tomato fruits (FTFs) between the year 2021, 2022 and 2023, respectively. In the year 2023 the company recorded extremely high quantity of VLWs which could be attributed to the large supply of fresh tomato fruits from various suppliers, and this indicates large quantity of spoils and discards were recorded in the same year of 2023 [16].

In the year 2021 8.20% of VLWs and it is higher than that of the year 2022 that recorded 3.40% especially with respect to the spoils and discards; while the year 2023 recorded 44.6% taken the lead in spoils of 107,914.60 Kg and peels of 406, 396.00 Kg; and between the year 2021 to 2023, total estimated dry peels record is 427,874.22 Kg; while total estimated for spoils and discards were 123,147.60 Kg and 11,873.23 Kg, respectively [16].

However, this ugly experienced economic loss can be avoided if the management of ALDUSAR did not relax the supply standard in the HACCP plan and also a reliable supplier that is engaged should be faithful to the agreements of both parties by supplying wholesome FTFs for crushing operation. And the peels are recovered from the crushing machine (Plate 2) of the fresh tomato processing factory; and these peels must be collected aseptically by trained staffs to avoid unnecessary contamination from either the staff or the containers used for collection of the peels from the rollers.



Plate 2: Partially processed tomato peels (PPTPs) before being conveyed by the rollers to the stainless collection point [16].

The plate 2 above represents the PPTPs that are ready for collection at the roller point. It is expected that the PPTPs should be immediately collected safely and processed further. And PPTPs is likely to be rich in soluble-fibre; thus, this could imply that the use of these wastes generated during the processing of fresh tomato fruits the end product ‘foods companion’ would be rich in soluble fibre serving as roughages for the consumers [16].

Can these FLW generated from the fresh tomato fruits processing plant be used to prepare safe ‘foods companion’?

Materials and Methods, Results and Discussion

Materials

All the materials required for the preparation of ‘foods companion’ were sourced from ALDUSAR foods and beverages limited; a fresh tomato processing factory located at Katsina, Katsina state, Nigeria. And the wastes were collected at various waste collection points that are safely collected. Other fresh vegetables including fresh hot pepper, sweet pepper, onion, garlic and ginger were bought from the Katsina Central Market Additional materials used for the preparation of ‘foods companion’ include weighing balance, a stainless pot, stirrer, thermometer, measuring cylinder, plastic bowl, spoon, cup, gas cooker, and PETs containers.

Experimental design

Food loss and waste used for the preparation of foods companion were collected aseptically at various waste generated points using sterile containers; the foods companion was prepared using HACCP plan and all preparation stages were done under hygienic conditions [16]. And Microbiological evaluation was conducted on the foods companion. All data were recorded in duplicates and results were converted to log and presented in tables, respectively [10,13,16].

Methodology

Raw materials, ingredients/recipes formulations

To have a control over the preparation of samples of foods companion, all raw materials and ingredients formulations were established after three trial production methods.

Raw materials formulation and preparation of ‘foods companion’

The preparation of foods companion was done in various stages namely waste collection, waste assessment, waste weighing and blending, waste thermal treatment, weighing of fresh vegetables and mixing of all ingredients and other additives for the preparation of foods companion [16]. The major raw materials used for the production of foods companion include: (a) slices of fruits of fresh tomatoes (SFFTs), (b) processed tomato peels (PTPs) generated by the pulper and (c) Tomato paste (TP)/tomato concentrate (TC) generated at the concentrator usually collected before CIP operation. Also, other raw materials that were used include: (i) processed fresh sweet pepper puree, (ii) processed fresh hot pepper puree, (iii) processed fresh onion puree, (iv) iodized salt and (v) potable water. Also, other optional raw materials serving as flavourants and create varieties in the ‘foods companion’ including (I) processed ginger paste, and (II) garlic paste.

Recipe formulation for the three samples of the foods companion

S/NO	Ingredients	Quantity(grams/ml)	Quantity(grams/ml)	Quantity(grams/ml)
		Sample 515	Sample 517	Sample 519
1	Processed Fresh Tomato Fruits Peels (WST-01)	250 (27.49%)	250 (27.49%)	250 (27.49%)
2	Tomato Paste Waste (WST-02)	250 (27.49%)	375 (41.24%)	250 (27.49%)
3	Processed Fresh Sweet Pepper (FRM-01)	125 (13.75%)	Nil (0.00%)	125 (13.75%)
4	Processed Fresh Hot Pepper (FRM-02)	125 (13.75%)	250 (27.49%)	Nil (0.00%)
5	Processed Fresh Onions, Garlic and Ginger (FRM-03)	125 (13.75%)	Nil (0.00%)	250 (27.49%)
6	Potable water (PRM-01)	25(2.75%)	25 (2.75%)	25 (2.75%)
7	Salt (PRM-02)	9.3 (1.02%)	9.3 (1.02%)	9.3 (1.02%)
8	Citric Acid (CA)	GMP	Citric Acid (CA)	GMP
9	Benzoic Acid (BA)	GMP	Benzoic Acid (BA)	GMP
	Total	909.3 (100%)	909.3 (100%)	909.3 (100%)

Table 3: List of ingredients and the quantity used per unit batch.

Process methods for the preparation of foods companion

The process method include weighing, formulating, homogenizing, heat-processing, acidification, preservation, rapid cooling and packaging (Figure 3), respectively [16,17].

The process flow diagram elaborately and vividly presented. All the unit operations adopted for preparation are well-coordinated and critically employed as required in the preparation of the samples of the foods companion.

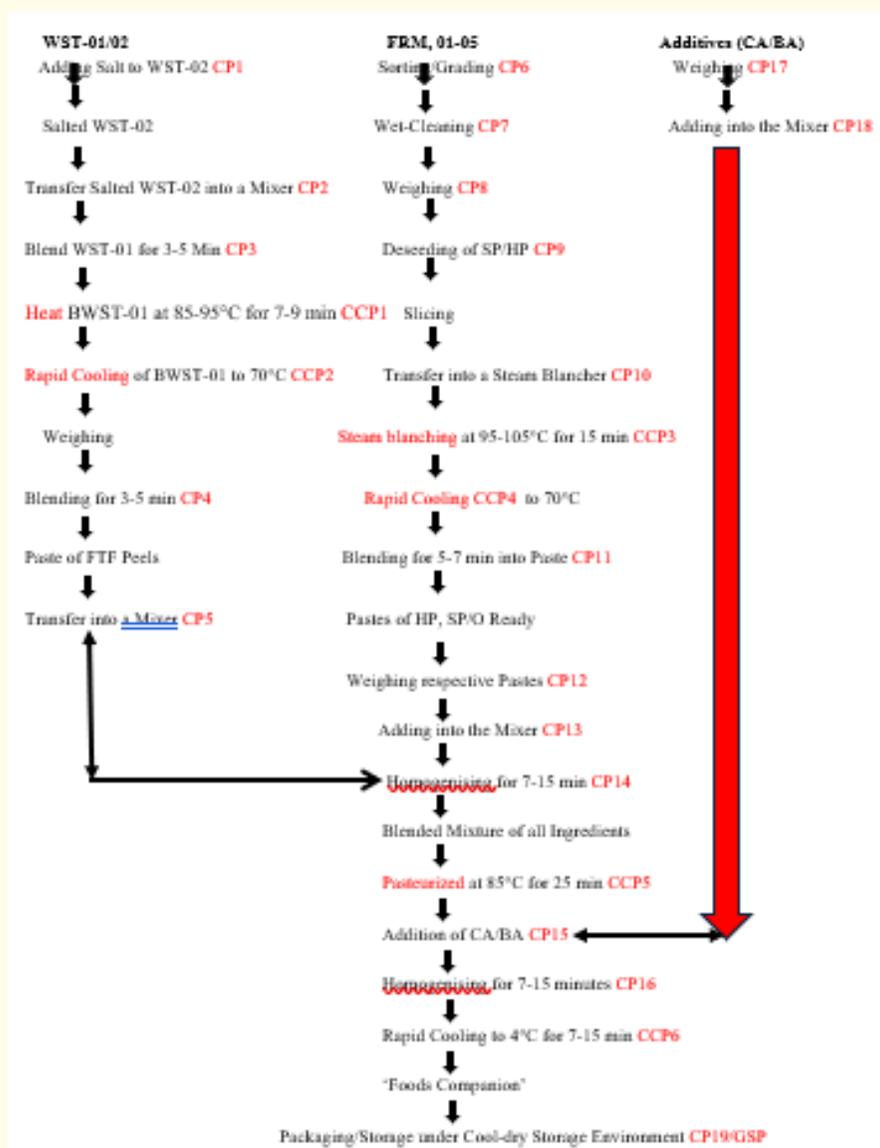


Figure 3: Process flow diagram for the preparation of foods companion from several food wastes, other processed raw materials and food additives [16].

Figure 3 above present all the unit operations, standard operating procedures (SOPs), control point (CPs) and critical control points (CCPs) used and adopted for the safe preparation of 'foods companion'.

Procedure for the processing of collected processed FTFs peels

1. Processed FTFs peels should be collected aseptically in sterile containers via the collection point;
2. It was heat treated at 85 - 95°C for 5 - 10 minutes with a measurable amount of potable water;

3. The weighed processed FTFs peels is then blended for 3 - 5 minutes;
4. A partially processed FTFs peels is then weighed and transferred into a stainless container;
5. Fully processed FTFs is ready to be mixed with other ingredients in items ii-iv.

Procedure for the production of pastes from fresh onion, sweet pepper and hot pepper

1. Fresh sweet peeper (FSP), fresh hot pepper (FHP) and fresh onions, garlic and ginger (FOs) are to be weighed, respectively;
2. They (prepared FSP, FHP and FOs) are to be sorted and graded and washed with clean water;
3. They are to be deseeded (for FSP and FHP) and the flesh were sliced into tiny pieces;
4. They (prepared FSP, FHP and FOs) are to be transferred into stainless pots with addition of potable water and was steam blanched for about 95°C for 15 minutes, respectively;
5. They (prepared FSP, FHP and FOs) are to be then blended into paste and make ready for further processing, which is to be mixed with other processed wastes and ingredients.

Procedure for the collection of tomato paste wastes

The tomato paste waste at the evaporator, in the concentrator, in the pipes and in the pasteurizers and other established points in the food production area, should be scooped, washed and rinsed out using potable water; and should be weighed and transferred into a clean stainless container [16].

Procedure for the production of 'foods companion'

1. The fully processed FTFs peels, FSP, FHP, FOs and TP waste are to be weighed according to the recipe formulation;
2. All the above are to be transferred into a stainless homogenizer (mixing machine);
3. All were thoroughly homogenized for 10 to 25 minutes;
4. The foods companion is to be heated for 25 minutes at 85°C;
5. Addition of benzoic acid and citric acid according to the good manufacturing practice (GMP) and as in the recipe formulation;
6. It (Homogenized foods companion) is to be cooled rapidly to about 0 - 4°C to ensure thermal shock;
7. It is to be packaged in plastic containers and PET bottles of various capacities
8. And the packaged foods companion is store in a cool-dry environment condition.

Microbiological status determination of the prepared foods companion

Preparation of samples and culture media

Samples of foods companion prepared were mixed in a Stomacher bag using a Stomacher (400 laboratory blender Type BA, 7021 Model, England, UK.). Serial dilutions were prepared, inoculated on selective media and incubated at 37°C for 24 - 48 hr. After incubation colonies were counted using the method of [7,13,24]. Also, all the culture media (i.e. Agar) used in this study was prepared according to the instructions of the respective manufacturers.

Microbiological analysis of samples of prepared foods companion

Ten (10) ml of each samples of foods companion was homogenized with 90 ml sterile buffer peptone water. Further ten-fold serial dilutions of the resultant homogenates were made to obtain 10^{-2} , 10^{-3} , 10^{-4} and 10^{-5} respectively [12,13]. From the appropriate dilutions, 0.1 ml was plated in replicate onto different media [Sabouraud Agar (SA), Potato Dextrose Agar (PDA), and Yeast Extract Agar (YEA),

Oxoid Grades] using pour plate technique. At the end of the incubation periods, colonies were counted using illuminated colony counter (Gallenkamp, England). The counts for each plate were expressed as colony forming unit per ml of sample homogenate (cfu/ml) [4,7,11,13,24].

Viable bacterial cell count

After overnight incubation, growth on the plate count agar (PCA) (Oxoid grade) showing viable cells colonies of 30 to 300 were identified and counted. And the bacterial count was expressed as the number of colonies multiplied by the dilution factor [13,24].

Results for microbiological analysis

This part of the study presents and discusses the results of the microbiological status conducted on the samples of foods companion prepared using HACCP Plan [10,13,14].

Samples code	Microbial cell loads (cfu/g)	Converted value (log ₁₀ cfu [#])
515	< 1.0 x 10 ¹	1.00
517	< 1.0 x 10 ¹	1.00
519	< 1.0 x 10 ¹	1.00

Table 4: Results of the total plate count of the samples of prepared foods companion.

Table 4 presents the results of the microbiological status conducted on samples of foods companion prepared, respectively.

Samples code	Microbial cell loads (cfu/g)	Converted value (log ₁₀ cfu [#])
515	< 1.0 x 10 ¹	1.00
517	< 1.0 x 10 ¹	1.00
519	< 1.0 x 10 ¹	1.00

Table 5: Results of the yeasts/moulds cells count of the samples of prepared foods companion.

Table 5 presents the results of the yeast/moulds status conducted on samples of foods companion prepared.

The results of the microbiological analysis of three samples of foods companion show count of less than ten (10) cells counts indicating the impact of HACCP plan adopted and used for the preparation of foods companion. Hence, results of microbial analyses predict that the foods companion samples are microbiologically safe for human use and consumption. Also, in addition, foods companion containing citric and benzoic acids, as highly water soluble acid, can interact with pH to inhibit the growth of yeasts, moulds and bacteria supporting the theory of the fact that anti-microbial effect of these acids is due to a lowering of the pH [25]. Also, the three samples of the foods companion contained appreciable quantities of both benzoic and citric acids coupled with the processing technique (HACCP plan) employed before being packaged into the primary package; and it is expected that ready-to-eat foods should not contain pathogens in them with the exception of moulds, yeasts and a few acid-tolerant bacteria that may likely grow and proliferate over period of time [24]. Hence, this study established that microbial cells that were detected from all the three samples of the Foods Companion are within the satisfactory (10³ cfu/g) and marginal (10³ to < 10⁵ cfu/g) microbial limits for RTE foods [11,12].

Conclusion

The preparation of “foods companion” was achieved by the application of HACCP plan and also all the raw materials processed and/or reprocessed have conformed to the requirements of the food safety act of 1990. The foods companion was prepared from processed

peels of fresh tomato fruits, fresh tomato paste, fresh sweet pepper, fresh hot pepper, fresh onions, garlic and ginger, potable water, salt, citric acid (E300) and benzoic acid (E210). The three samples of the 'foods companion' are microbiologically safe for human use and/or consumption. If the 'foods companion' are scale-up and commercialized this will serve as a source of revenue generation to the tomato paste production companies; hence "Wastes have been converted to wealth" and environmental pollution would be minimized and prevented from the wastes usually generated during the crushing operations of fresh tomato fruits.

Acknowledgement/Special Notification

The authors of this study sincerely appreciate the management of ALDUSAR food and beverages limited, Katsina, Nigeria for allowing them to use the mini food processing workshop under the research and development department and well-equipped laboratory to conduct microbiological and physico-chemical analyses during this study.

Also, this developed foods companion is on the process of patenting for ALDUSAR food and beverages Limited, Katsina, Nigeria; hence no person or group of persons companies is/are allowed to use the recipes formulation and the developed process reported in this study. However, interested captains of food industries and/or person(s) can consult the corresponding author for business details.

Conflict of Interest

Authors declare no conflict of interest in the cause of this study.

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