

Investigation and Control of Tomato Production Plant

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Abstract

The demand for tomato paste is daily used over the year with the fact that it is abundant in certain seasons and scarce during other season. Many methods are used to preserve the juice or the paste through drying and with addition of preservative. Tomato grows under ambient conditions or in green houses at a temperature of 20°C - 27°C with high contents of vitamins A and B, potassium, iron, and phosphors. Tomato is a source of fiber; it doesn't contain sodium salt, fats, or cholesterol; in fact it is the cheapest food of the poor common people. Tomato while waiting for processing to paste deteriorates rather quickly, and shall be thoroughly rinsed with sterilized clean water using rotary washers. The washed tomato is inspected, sorted, and chopped. The tomato liquor is processed through an extraction unit where the juice is separated away from outer skin, seeds and fibers. To avoid oxidation and foaming the tomato liquor is deaerated; the juice is deaerated by taking the vacuum as soon as it is formed. A double-effect evaporator is used to concentrate the tomato liquor under partial vacuum of 0.5 atmospheres; this is important to minimize heat damage, oxidation and dark color. The tomato paste is then sterilized with small amount of non-harmful preservatives and then canned, labeled and sent to store. To achieve the international standard specifications and metrology organization a control system is developed, tuned and analyzed for stability conditions. It is recommended that a tomato production plant has to be constructed in countries like Sudan and other countries with similar weather conditions.

Keywords

Tomato Paste, Sterilization, Control, Food Processing Technology, Food Science & Technology

1. Literature Review

Tomato paste is thick paste made by processing tomatoes to reduce its moisture content, by evaporating in double or triple-effects evaporates [1] [2] [3]. Tomato is valuable raw material for very wide range of foods and always needed by the food industries. Tomato is crushed and concentrated to paste; the simplest method for processing tomato paste consists of washing, sorting, pulping, extraction, mixing with salt, preservatives and the canned [4] [5] [6]. Tomato is considered as a source of vitamin A, B and C, with considerable amount of potassium, iron and phosphorus [7] [8] [9]. The demand for processing tomato to paste is that high seasonal production of tomato happens in short period, difficult to be stored, get rotten and spoiled to waste [10] [11].

Tomato is collected from farms, sorted and washed to remove dirt and re-sorting again. Washing is an ultimate process that has to be controlled. Tomato crushing is a necessary step after which the seeds and peels are separated [12] [13] [14]. Washing removes molds, insects, drosophila eggs and other contaminants. The efficiency of washing determines the microbial count [15] [16]. As tomato is acidic, it has to be sterilized; tomato-heating process is carried out at temperature of 90°C under partial vacuum to minimize heat damage and oxidation [17] [18]. The type of evaporators used must be optimized; single effect has steam economy of less than unity, while double and triple effects have steam economy of greater than 2 [19]. Often the vapors generated in food concentration processes contain various volatile compounds with characteristics of special food flavor; sometime the flavor volatiles are stripped from the vapor and returned to the finished product. A control system has to be designed, with specific control strategy [20] [21]. The control is important to insure the quality satisfying the international standard specifications. The system transfer functions need to be identified tuned and checked for stability analysis. The system is to be simulated and the type of controller has to be nominated in each control loop [22] [23].

Objectives

- 1) Investigation of manufacturing tomato paste from improved local varieties.
- 2) Design and development of a control system to keep the quality of the paste up to international standard specifications.

2. Methodology

Experimental procedure

Fresh tomato was obtained from the market, well-sorted, washed, mixed by a mixing machine and filtered. 0.5% of common salt and 0.5% sodium citrate were added while mixing for 10 minutes [24]. The tomato liquor was then introduced in a laboratory scale double-effect evaporator to concentrate the juice to 70% solid. The thick liquor juice is then further dried to 20% moisture in a rotary dryer; the paste is then packed in small plastic cans [25].

The washing, sorting and mixer equipment are to be selected according to the capacity of the plant. The type of evaporator is double-effect that will be designed and controlled [26]. The dimensions including the diameter of the calandria, the surface area, the number of tubes and height of the effects are determined. A control strategy is developed, the transfer functions are identified, and using the overall transfer functions the system is simulated and the controller that gives minimum overshoot is selected [27].

Design Procedure

From material and energy balances the major equipments are designed and their dimensions are tabulated [28].

Controllers tuning and stability:

- The transfer functions are specified (G_c, G_v, G_p, G_m).
- The characteristic equations are calculated.
- Routh and Z-N are used to get the adjustable parameters (K_c, τ_i, τ_D).
- The systems are simulated for each loop; the type of controller is selected and installed into the control loop.

3. Results and Discussion

Design of double-effect evaporator

Table 1 summarizes the design of the double-effect evaporator.

The material of construction used for tube and shell is stainless steel. **Figure 1** and **Figure 2** highlight the evaporator's both backward and forward feeds.

Table 1. Summary of the design.

Title	First effect	Second effect
Heating surface area, m ²	39	41.0
Length of tube, m	5	5
Height of effect, m	7	7
Pitch of tube, m	0.07	0.07
Number of tubes	62	62
Thickness of tube and shell, mm	15	15

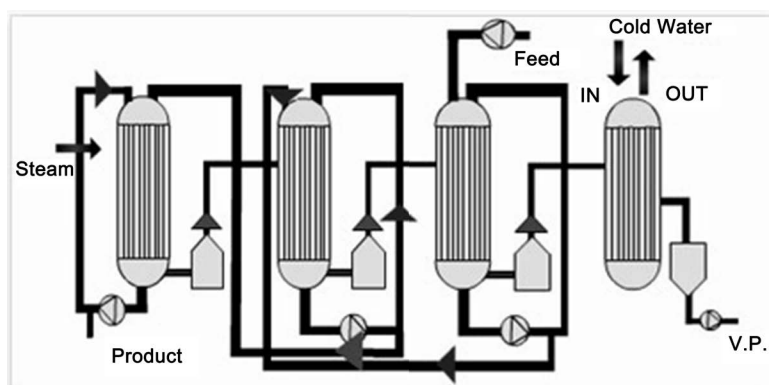


Figure 1. Backward feed for double effect evaporator.

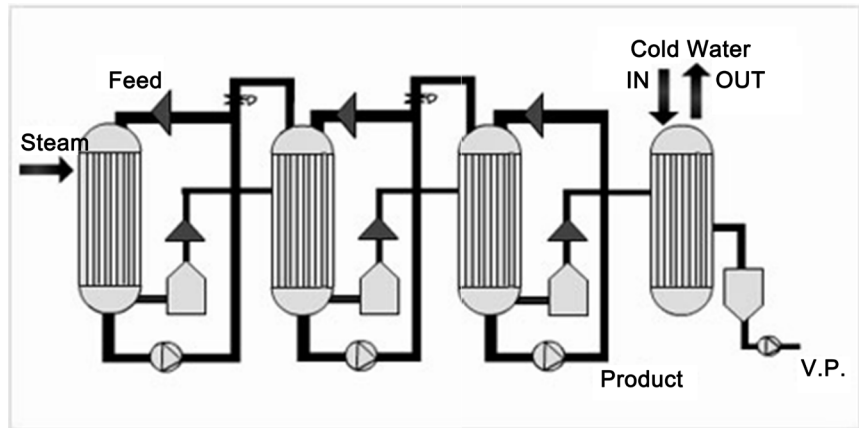


Figure 2. Forward feed for double effect evaporator.

Transfer Functions Identification:

$$G_c = K_c$$

$$G_v = \frac{10}{S+1}$$

$$G_p = \frac{15}{(S+1)(2S+1)}$$

$$G_m = 1$$

$$OLTF = \frac{K_c}{100S^3 + 80S^2 + 17S + 1}$$

Bode Plot:

MATLAB Format:

```
num = [1];
```

```
den = [100 80 17 1];
```

```
sys = tf (num, den);
```

```
Bode (sys); grid.
```

Figure 3 shows Bode plot of the frequency of the system OPLTF against the amplitude ratio and phase angle.

From bode plot we get the critical gain K_c and critical period PU.

These are used to get the adjustable parameters K_c , τ_i and τ_D as shown in **Table 2**.

4. Conclusion

It is concluded that a tomato paste is processed successfully with specification satisfying the international standards. The procedure to process the tomato paste is simple including washing, sorting, pulping, juice extraction and evaporation. A control strategy was developed. The transfer functions were specified and the system is checked for stability and tuning. The control strategy includes the temperature to avoid oxidation, darkening of the color, and vitamin destruction. The composition and thickness of the paste are also controlled.

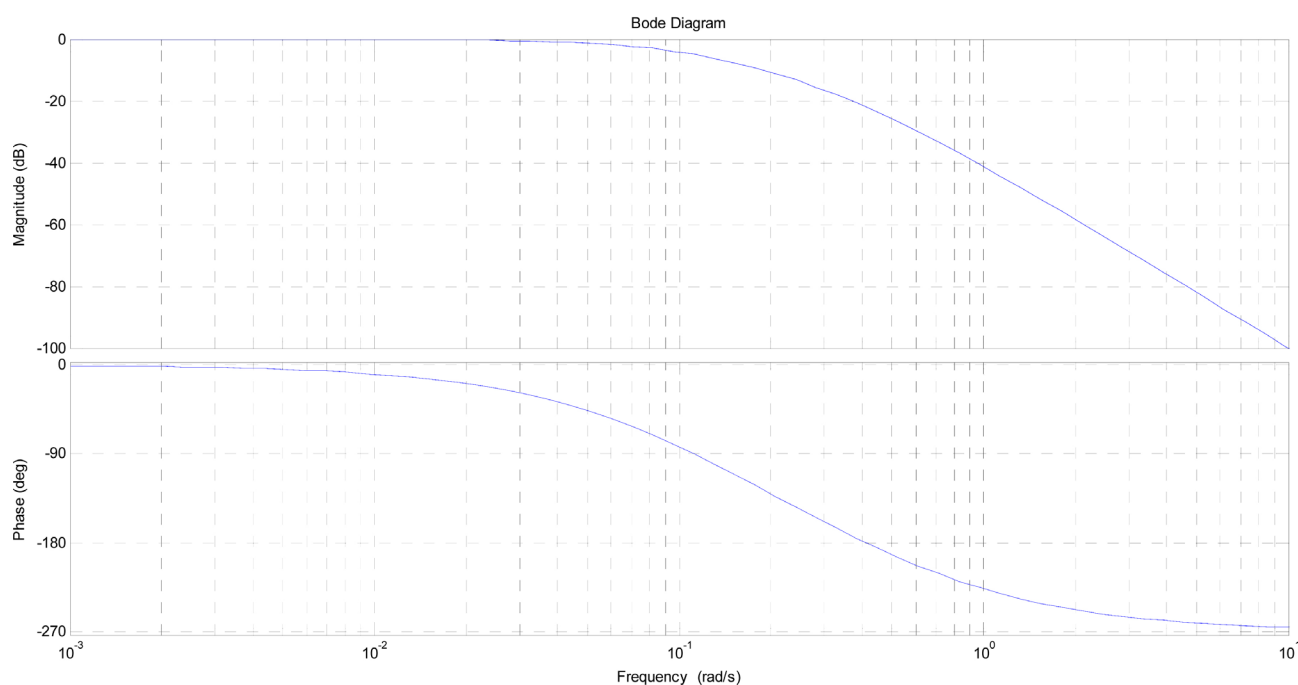


Figure 3. Bode plot.

Table 2. Bode plot and Z-N table data analysis.

Type of controller	K_c	τ_i , Sec	τ_D , Sec
P	6.275	-	-
PI	5.647	12.7	-
PID	7.53	7.62	1.9

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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