ENERGY ACCOUNTING
IN
CANNING TOMATO PRODUCTS

MASTER

RECEIVED
MAY 31 1979

N. F. P. A. - BERKELEY

by

R. Paul Singh
P. A. Carroad
M. S. Chhinnan
W. W. Rose*
N. L. Jacob*

Department of Agricultural Engineering
Department of Food Science and Technology
University of California
Davis, California 95616

112 1000

950 9703

*National Food Processors Association
Berkeley, California 94710

Paper for presentation at the
Annual IFT meeting
St. Louis, Missouri
June 10-13, 1979

~~DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED~~

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

ENERGY ACCOUNTING IN CANNING TOMATO PRODUCTS

R. Paul Singh, P. A. Carroad, M. S. Chhinnan, W. W. Rose, N. L. Jacob

ABSTRACT

An energy accounting method was used to determine energy use in various unit operations in canning tomato juice, whole-peeled tomatoes, and tomato paste. Data on steam and electric consumption were obtained from a canning plant with the use of steam flow meters and electric transducers. Unit operations associated with following equipment were investigated: crushers, hot-break heaters, pulpers, finishers, lye-bath peelers, evaporators and retorts. Data were analyzed to determine amount of energy used per unit of raw product. Energy intensive operations were identified for future modifications to reduce energy consumption.

INTRODUCTION

The industrial nations have become increasingly dependent on energy derived from non-renewable sources. The food industry depends heavily on such sources for processing foods. The recent increase in energy costs and sporadic shortages of certain types of fuel have emphasized the need to examine energy use in food processing. The study reported in this paper is part of a comprehensive project on accounting of energy in fruit and vegetable processing.

Energy analysis of food processing has been a subject of several recent studies. These include energy utilization in spinach processing (Chhinnan, et al., 1978), energy consumption of refrigerating, canning and freezing of peas by Rao (1977), energy requirements for concentration of foods by Schwartzberg (1977), energy use in citrus packing plants by Naughton, et al. (1979), and improvements of energy utilization of a continuous atmospheric retort by

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

W.O.M.

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Chhinnan, et al. (1978a) and Griffith, et al. (1979). Flink examined energy use in dehydration of foods (1977). Wilson, et al. (1978) evaluated energy use in meat processing plants. A computer program to estimate heat losses in food processing plants was developed by Rao, et al. (1978). A systematic approach to conduct energy accounting in a food processing plant was presented by Singh (1978).

The overall objective of this paper is to account for energy used in processing tomatoes for three products, namely, tomato juice, peeled tomatoes, and tomato paste.

MATERIALS AND METHODS

Data collection involved use of both electric watt transducers (Ohio Semitronics) to measure electrical energy and orifice plates (Foxboro) to measure steam flow. A data acquisition system (Autodata 9, Accurex) was used to monitor data from several locations within the processing plant.

DATA MONITORING

This study was conducted at the tomato canning plant, Sacramento Foods, Sacramento, California. Energy measurements were conducted in processing of three tomato products, namely, peeled tomatoes, tomato juice and tomato paste.

To facilitate electrical and thermal energy measurements, the entire processing plant was divided into fifteen stations. The location of several electrical panels in the plant influenced the selection of processing equipment for each station. On a given day energy measurements were conducted at one of the monitoring stations.

A list of all electrical motors used in tomato processing was prepared and since several same size electrical motors were used in multiple processing lines, representative motors were selected for monitoring each unit op-

eration. The transducers used for energy monitoring were also cataloged for receiving area, tomato canning, tomato juice processing, tomato paste and sauce production and waste-water reclamation.

In tomato processing, steam is used in such equipment as lye-bath peelers, hot-break tanks, heat-exchangers, retorts, steam turbine, Rotovac, and evaporators. Orifice plate flowmeters were used to measure steam in all cases except evaporator. The steam pipe to the evaporator was relatively large, 8-inch diameter, thus the steam flow to the evaporator was measured with a pitot-tube (Annubar). The quality of steam, was measured by the calorimetric method using a one gallon thermos flask partially filled with water.

The mass flow rate was measured for each product using the following approach. For juice processing, a Polaroid camera was installed above the inspection belt before tomatoes were conveyed to the crusher. The speed of the conveyor belt was noted along with its dimensions. At random, pictures were taken of tomatoes on the conveyor belt. From these pictures the number of tomatoes on the marked section of the belt were counted from several measurements, using an average mass per tomato, the product flow rate was computed. Similar approach was used for tomatoes processed for whole peeled tomatoes and paste/sauce operations. In addition to the above, the rate of cans processed in the retort was observed for juice and peeled tomato processing.

More information on procedures used in data collection are available in Chhinnan, et al. (1978).

The solid wastes from tomato processing lines were measured daily. In Table 1, the solid wastes for eight production days (three shifts each) are shown. On the average, 6 percent of tomatoes received were discarded in the

Table 1. Total solid wastes in tomato processing

Day	Tomatoes received for processing ton	Solid Wastes ton	Percent. Loss
1	1,854	96	5
2	1,400	83	6
3	1,333	85	6
4	1,316	68	5
5	1,383	90	7
6	1,460	63	4
7	1,246	100	8
8	700	49	7
Mean			6

form of solid waste. The solid waste typically consisted of peels, seeds, pomace, etc.

DATA ANALYSIS

All energy accounting computations are based on an eight-hour shift.

ELECTRICAL ENERGY

A computer program was written to compute time average values of electrical energy use. Most motors operated continuously during the eight-hour shift but some motors were shut off due to breakdown or lunch breaks. The computer values of time-average energy use were calculated for the total operating time of each motor.

THERMAL ENERGY

All equipment used in tomato processing operated continuously during the eight-hour shift. The steam flow rate was measured using the electronic DP cell (Foxboro). The indicated voltage values were converted to steam flow rate using computer programs. Steam quality values obtained for several replicate samples are presented in Table 2, clearly indicating the variation with the location of the equipment.

TOTAL ENERGY

Total energy consumed by individual equipment was calculated by summing up its electrical and thermal energy input. Electrical energy units (KWH) were changed to equivalent thermal energy units (Btu) by using a fossil-fuel conversion factor (10500 Btu/KWH).

RESULTS AND DISCUSSION

Energy Intensity of Tomato Processing

The thermal energy intensity for processing tomatoes into various pro-

Table 2. Average steam quality measured at respective equipment location

Equipment	Avg. Steam Quality*
Hot-break heater	0.89
Retort	0.79
Lye-bath peeler	0.85
Evaporator	0.92
Heat exchangers (Paste Line)	0.83

*These values are means of several replicate samples taken on different days.

ducts such as juice, peeled, sauce and paste can be obtained by examining the plant natural gas and oil consumption. In Table 3, data are presented for days when only tomatoes were processed. These six days represent the last days of processing season. Thermal energy intensity was computed for each day and the mean value is 538 Btu/lb of tomatoes received. It should be noted that this is a composite value representing processing of tomatoes into all aforementioned tomato products.

The electrical energy intensity was computed from the total plant electrical consumption for one month. Since during that month a small amount of peaches, pears and grapes were also processed, the energy intensity given in Table 4 is for all products. However, since tomatoes represent the major product processed (over 95% of total) this intensity value should be a reasonable estimate for tomato processing. The electrical intensity includes electrical consumption for processing, holding certain products like peaches and pears in cold storage prior to processing, operation of waste handling system, operation of boilers and freezer storage for frozen tomato paste. It needs mention that most other tomato paste production plants in California use aseptic filling and they do not require frozen storage of tomato paste.

Energy Accounting of Tomato Processing

The results on energy accounting of handling tomatoes at the receiving station, processing tomatoes for juice, peeled tomatoes and paste production are presented separately in the following sections:

Tomato Receiving: At the receiving station, the tomatoes were removed from gondolas using water. The field dirt carried by tomatoes was washed off and the water containing dirt was conveyed to the mud settling tank. The tomatoes were conveyed through an elevator and a water flume to the process-

Table 3. Thermal energy intensity of processing tomatoes

Day	Tomatoes received ton	Natural gas therm	Fuel oil gal.	Thermal energy intensity Btu/lb
1	1854	18,551	--	500
2	1400	9,323	2129	440
3	1333	15,523	813	625
4	1316			
5	1383	47,410	--	570
6	1460			
7	1246	11,990	--	481
8	700	8,554	--	611

$\bar{x} = 538$ Btu/lb

$\sigma = 75$

Table 4. Electrical energy intensity of processing tomatoes

Observation period (month)	Product received		Total plant electrical consumption (KWH)	Combine electric energy intensi KWH/1
	tomatoes (tons)	other (tons)		
1	49.174	2.669	1.307×10^6	0.012

ing area. Water was recirculated in the flume. This system handled approximately 670 tons in an eight-hour shift. The pump used in conveying water to the mud settling tank consumed the largest portion of energy in this system (Table 5).

Tomato Juice Production: The energy accounting diagram of tomato juice production for an eight-hour shift is presented in Figure 3. Most operations consumed electricity except hot-break heaters and retorts that use steam. The energy consumption values shown in the figure were for operating all equipment. For example, energy consumption of only one sorter belt was actually measured; since six sorter belts operate continuously during the eight-hour shift, the energy consumption shown in the figure is six times the value for one sorter belt. The energy intensive operations were hot-break heaters and retorts utilizing more than 97% of the total energy consumed (Table 6). In the hot-break heaters, the temperature of the product was raised from about 77°F to 180°F, the temperature at which pectic enzymes were inactivated. Theoretically, for 336 tons of tomatoes the energy required for hot-break operation should be 66.5×10^6 Btu. Since 75×10^6 were used, the energy use efficiency was 89%. In retorting canned tomato juice (at 186°F) was heated to 249°F in a pressure retort. Retorting 336 tons of tomato juice should theoretically require 38×10^6 Btu, however, actually 186×10^6 Btu were used, indicating an energy use efficiency of 20%. Both these operations and associated equipment require further research for needed modifications to reduce energy consumption.

Peeled Tomato Production: Figure 4 is the energy accounting diagram for peeled tomato production. The lye-bath peeler and retort required steam, remaining equipment operated on electricity. As seen in Table 7, the energy consumption of most measured operations was small compared to retort and

Table 5. Energy used in receiving area of handling approximately 650 tons of tomatoes during an eight-hour operation..

Equipment	Energy Consumption Electrical KWH
Elevator	9.236
Pump (to mud settling tank)	154.07
Flume, pump (water recirculation)	17.98
Elevator	7.60

Figure 3. Energy accounting diagram of tomato juice production.

Table 6. Energy used in processing 336 tons of tomatoes for juice production during an eight-hour shift

Process Equipment	Measured per unit equipment		Estimated total energy consumption			% of total energy consumption for processing
	Electrical KWH	Thermal 10 ⁶ Btu	Electrical KWH	Thermal 10 ⁶ Btu	Total 10 ⁶ Btu	
Sorter (6)*	1.6	-	9.6	-	0.1	0.04
Crusher (6)	21.6	-	129.6	-	1.36	0.61
Pump (6)	10.4	-	62.4	-	0.66	0.30
Hot Break (3)	12.0	25	36.0	75	75.38	33.90
Pump (3)	27.2	-	81.6	-	0.86	0.39
Pulper (4)	56.8	-	227.2	-	2.39	1.07
Finisher (4)	11.2	-	44.8	-	0.47	0.21
Pump	12.8	-	12.8	-	0.13	0.06
Screw Press & Conveyors	5.39	-	5.39	-	0.06	0.03
Filler/Seamer (4)	13.98	-	55.90	-	0.59	0.27
Retort (6)	18.4	25.2	110.4	139.2	<u>140.36</u>	<u>63.12</u>
				Total	222.36	100.00

*Number in parenthesis refers to the total number of equipment used.

Figure 4. Energy accounting diagram of peeled tomato canning.

Table 7. Energy used in processing 220 tons of tomatoes for peeled tomato canning during an eight-hour shift

Process Equipment	Measured per unit equipment		Estimated total energy consumption			% of total energy consumption for processing
	Electrical KWH	Thermal 10 ⁶ Btu	Electrical KWH	Thermal 10 ⁶ Btu	Total 10 ⁶ Btu	
Size Grader (2)*	1.23		2.45		0.03	0.02
Roller/Washer (1)	7.2		7.2		0.08	0.05
Recirculation Pump (1)	5.55		5.55		0.06	0.03
Elevator (1)	1.49		1.49		0.02	0.01
Lye-Bath (1)	43.1	30.8	43.1	30.8	31.25	18.07
Conveyor (1)	0.85		0.85		0.01	0.01
Rubber-disc Peeler (1)	28.9		28.9		0.30	0.17
Elevator/Conveyor (1)	1.6		1.6		0.02	0.01
Sorter (1)	2.4		2.4		0.05	0.02
Slicer (2)	4.3		8.6		0.09	0.05
Conveyors (2)	0.91		1.92		0.02	0.01
Filler (4)	19.9		79.6		0.84	0.49
Retort (6)	18.4	23.2	110.4	139	140.16	81.06
				Total	172.91	100.00

*Number in parenthesis refers to the total number of equipment used.

peeler. The peeler used excessive amounts of steam, most of it was lost through incomplete steam condensation and lack of insulation on the equipment. Although energy consumption of retorting of peeled tomatoes was not measured, it was estimated to be high based on results from juice production. Thus, further research is needed to modify lye-bath peelers and retorts to reduce energy wastage.

Tomato Paste Production: Figure 5 is the energy accounting diagram of tomato paste production. Operations that use sorter, pulper and finisher were similar to those used in juice production. Vertical heat exchangers were used to achieve heating for hot-break operation. Steam was used in these heat exchangers and the evaporator area for concentrating tomato juice into paste. In Table 8 are listed the energy consumption values for all process equipment involved in paste production. As expected the major portion of energy was used in the evaporator.

CONCLUSIONS

- 1) The average thermal and electrical energy intensities of canning tomato products were 538 Btu and .0126 KWH per pound of tomatoes received, respectively.
- 2) In tomato juice production, hot-break and retort operations were most energy intensive.
- 3) In canning of peeled tomatoes, lye-bath peelers and retorts were most energy intensive.
- 4) In tomato paste production, hot-break operation and evaporation were most energy intensive.
- 5) Further research to develop design modifications of equipment used in hot-break, retorting, peeling and evaporation is needed. These operations require major energy-related improvements.

Figure 5. Energy accounting diagram of tomato paste production.

Table 8. Energy used in processing 386 tons of tomatoes for paste production during an eight-hour shift

Process Equipment	Measured per unit equipment		Estimated total energy consumption			% of total energy consumption for processing
	Electrical KWH	Thermal 10 ⁶ Btu	Electrical KWH	Thermal 10 ⁶ Btu	Total 10 ⁶ Btu	
Sorter (5)*	1.6		8.0		.08	0.03
Crusher (5)	21.6		108.0		1.13	0.37
Pump (5)	10.4		52.0		0.55	0.18
Heat Exchanger (horizontal) (1)		5.88		5.88	5.88	1.95
Heat Exchanger (vertical) (4)		20.14		80.56	80.56	26.41
Pulper (3)	56.8		170.4		1.79	0.59
Finisher (3)	11.4		34.2		0.36	0.12
Pump (1)	8.54		8.54		0.09	0.03
Pumps (1)	4.27		4.27		0.04	0.01
Evaporator (2)	5.6	171.00	11.2	171.00	171.12	56.10
Pump (1)	7.2		7.2		0.08	0.03
Pump (1)	4.77		4.77		0.05	0.02
Rotovac (2)	34.67	42.80		42.80	42.80	14.05
Pump (1)	3.01		3.01		0.03	0.01
Pump (1)	8.00		8.00		0.08	0.03
Chiller-Pumps (5)	6.93		34.67		0.36	0.11
				Total	305.00	100.00

*Number in parenthesis refers to the total number of equipment used.

REFERENCES

1. Chhinnan, M. S., R. P. Singh, and L. D. Pedersen. 1978a. Improvements in energy utilization of an atmospheric retort. Paper presented at the 38th Annual Meeting of the Institute of Food Technology, Dallas, Texas.
2. Chhinnan, M. S., R. P. Singh, L. D. Pedersen, P. A. Carroad, W. W. Rose, and N. L. Jacob. 1978b. Analysis of energy utilization in spinach processing. Paper presented at the Winter meeting of Am. Soc. of Agri. Engrs., Chicago, Ill. Paper No. 78-6524.
3. Flink, J. M. 1977. Energy analysis in dehydration processes. Food Technology 31(3):77.
4. Griffith, H. E., A. Malvick, and K. Robe. 1979. External heat exchangers on retorts save TVG \$59,000/yr. Food Processing 4(5):156-158.
5. Naughton, M., R. P. Singh, P. Hardt, and T. R. Rumsey. 1979. Energy use in citrus packing plants. Trans. of ASAE 22(1):188-192.
6. Rao, M. A. 1977. Energy consumption for refrigerated, canned and frozen peas. J. of Food Process Engineering 1(2):149-165.
7. Rao, M. A., J. Katz, and V. K. Goel. 1978. Economic evaluation of measures to conserve thermal energy in food processing plants. Food Technology 32(4):34.
8. Schwartzberg, H. G. 1977. Energy requirements for liquid food concentration. Food Technology 31(3):67.
9. Singh, R. P. 1978. Energy accounting in food process operation. Food Technology 32(4):40.
10. Wilson, P. W., F. C. Knopf, and M. R. Okos. 1979. Energy utilization in meat processing plant. Paper presented at the Winter meeting of the Am. Soc. of Agri. Engrs., Chicago, Ill. Paper No. 79-6507.

ACKNOWLEDGEMENTS

The research was supported by Project 2969 MH, University of California Agricultural Experimental Station and contract # DE-AC07-78CS40 191, Department of Energy, Washington, D.C.

The authors acknowledge technical assistance of C. Zuritz, K. Boisseri and B. Hitomi.

Reference to a company or product name does not imply approval or recommendation of the product to the exclusion of others that may be suitable.