CHAPTER 14

Reformulation of a Cheese Sauce and Salsa to Be Processed Using Pulsed Electric Fields

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ABSTRACT

CHEESE sauce and salsa are not suitable for PEF treatment due to their salt content, viscosity, and particle size. Salsa and cheese sauce products were reformulated so that the electrical conductivity was minimized, and the particle size was reduced. For each product, the electrical conductivity, density, and viscosity were evaluated at temperatures ranging from 4°C to 80°C. Energy input and temperature rise during PEF processing, so pumping requirements were calculated for temperatures from 4°C to 80°C. The reformulated products were suitable for PEF processing.

INTRODUCTION

Pulsed electric field (PEF) processing is a nonthermal method used to increase shelf life and assure food safety by inactivating spoilage and pathogenic microorganisms. This method of preservation minimizes the increase in product temperature during processing, which maintains the flavor, color, and nutritional value of the product (Dunn and Pearlman, 1987; Jin and Zhang, 1999; Jin et al., 1998; Jia et al., 1999). This process is used in combination with, or in replacement of, thermal sterilization methods. To process a food with PEF in a continuous system, the food flows through a series of treatment zones, with a high voltage electrode on one side of each zone, and a low voltage electrode on the other. The PEF process is defined by the electric field strength, or the voltage applied per distance between electrodes, and the treatment time.

This method has proven successful in a variety of liquid products with a relatively low viscosity and electrical conductivity (Zhang et al., 1994; Jin et al., 1998; Mizuno and Hori, 1988). However, PEF has not yet been successfully used for processing products with high electrical conductivity, high viscosity, or large particle size.

The physical properties of the foods being processed, including electrical conductivity, viscosity, and density, are very important when designing and operating a PEF process (Ruhlman et al., 2001). Operational conditions need to be adjusted to accommodate products with a high electrical conductivity and viscosity, like cheese sauce and salsa. These adjustments include: PEF process parameters, fluid handling system design, and the physical properties of the food. The presence of salt contributes to the high electrical conductivity of cheese sauce and salsa. By preparing the products to be PEF processed without salt, the electrical conductivity can be reduced to meet the limitation of our PEF system. The appropriate concentration of salt can be aseptically added to the product after PEF processing.

The objective of this study was to reformulate salsa and cheese sauce to meet the requirements of the PEF system in terms of electrical conductivity and viscosity. This is the first step toward successfully using PEF for processing highly viscous foods or foods with large particles.

METHODS AND MATERIALS

For this study, the salt indicated in Table 14.1 (salsa) and Table 14.2 (cheese sauce) was omitted from the formulation until after PEF treatment to eliminate excess conductivity.

SALSA

Two salsa products were formulated using fresh ingredients, spices, and salt (Table 14.1). To process particulate foods, the treatment chamber was

TABLE 14.1. Two Salsa Formulations.

Salsa #1	Salsa #2
88% Tomatoes	69% Tomatoes
5.5% Cilantro	12% Green peppers
2.8% Lemon juice	12% Green onions
1.7% Green onions	3.6% Lemon juice
0.9% Cayenne pepper sauce	2.9% Jalapeño chilees
0.5% Cumin	0.5% Crushed garlic
0.5% Crushed garlic	[0.7% Salt]
[1% Salt]	

[ ] Indicates that salt is to be added after PEF processing.

TABLE 14.2. Two Cheese Sauce Formulations.

Cheese Sauce #1	Cheese Sauce #2
81.25% De-ionized water 15% Protein (18.75% MPC) 0.75% Sodium citrate 0.5% Cheddease 715 [1% Salt]	81.25% De-ionized water 15% Protein (18.75% MPC) 0.50% Sodium citrate 0.5% Cheddease 715 [1% Salt]

[ ] Indicates that salt is to be added after PEF processing.

redesigned to provide an inner diameter of 0.635 cm. The size of the particles in the salsa was reduced to approximately 1/8 in. (0.317 cm) by blending in a Waring blender. Since salt influences the electrical conductivity of the food, the formulations were prepared without added salt. The electrical conductivity and apparent viscosity were measured at 4°C, 22°C, 30°C, 40°C, 50°C, 60°C, 70°C, and 80°C.

CHEESE SAUCE

Two cheese sauce products were formulated using milk protein concentrate (Alapro 4850, New Zealand Milk Products, Inc.), de-ionized water, sodium citrate, salt, and enzyme modified cheese (Land O'Lakes Cheddease 715 Cheese Powder) (Table 14.2). After the sodium citrate was added, the mixture was heated to 60°C to aid emulsification, and then cooled to room temperature. The two formulations differ only in the amount of sodium citrate added, because sodium citrate affects both the viscosity and the electrical conductivity of the product. The electrical conductivity and apparent viscosity were measured at 4°C, 22°C, 30°C, 40°C, 50°C, and 60°C. In order to see the effects of the sodium citrate and added heat on the apparent viscosity, three sets of data were gathered: all ingredients, except sodium citrate, were mixed and the product was refrigerated before viscosity measurement; all ingredients, including sodium citrate, were mixed and the product was refrigerated before viscosity measurement; and all ingredients were mixed, heated to 60°C, and then refrigerated before viscosity measurement.

MEASUREMENTS OF PHYSICAL PROPERTIES

The electrical conductivity of both products was measured using a Yellow Springs conductivity meter (model 30/10 FT, YSI Incorporated, Yellow Springs, OH). The apparent viscosity of the salsa was measured using a Brookfield rotational viscometer (model DV-II+ with spindle LV #1 at 30 and 100 RPM, Brookfield Engineering Laboratories, Stoughton, MA). The apparent viscosity of the cheese sauce was measured using a Brookfield HBDVII+ cone and plate viscometer with spindle cp-40 at shear rates of 75, 350, and 375 s^{-1} (Brookfield

Engineering Laboratories, Stoughton, MA). For both products, the density was measured at room temperature using a Fisher Scientific pycnometer (Fisher Scientific, Pittsburgh, PA), and the specific heat was calculated using a model estimation for materials of high water content (Singh and Heldman, 1993).

CALCULATIONS

The maximum possible temperature change per pair of treatment chambers (ΔT), and total energy input during treatment per pair of chambers (P), were calculated for both products at all temperatures using the following equations:

$$\Delta T = (E^2 t\sigma/\rho C_p)/n$$
$$P = E^2 t\sigma/n$$

The variables in these equations are electrical conductivity (σ), density (ρ), and specific heat (C_p), and they are specific for each product. For the calculations, the PEF system designed for processing orange juice was used as an example (Zhang, 1997), where:

E = electric field strength (3.2×10^6 V/m)
t = total treatment time (9.0×10^7 s)
n = number of pairs of treatment chambers (6)
D = treatment zone diameter (4.8×10^{-3} cm)

The viscosity was used to determine the pumping requirements in the treatment chamber, which were calculated using a microsoft Excel spreadsheet designed specifically for our pilot plant design.

RESULTS AND DISCUSSION

SALSA

Commercial salsa products that contain salt, have an electrical conductivity of about 2.5 S/m, approximately 7 times higher than that of orange juice (0.35 S/m). Products with higher electrical conductivity require more energy input and better temperature control during PEF processing. The current PEF process system cannot meet the requirements. Since salt is a major contributor to the electrical conductivity of the product, the best solution would be to eliminate the salt from the product. However, with salsa, the acceptability of the product flavor is compromised. We suggest that salsa should be prepared without salt for PEF processing. Before packaging, the salt can be aseptically added to the salsa as a sterile salt solution.

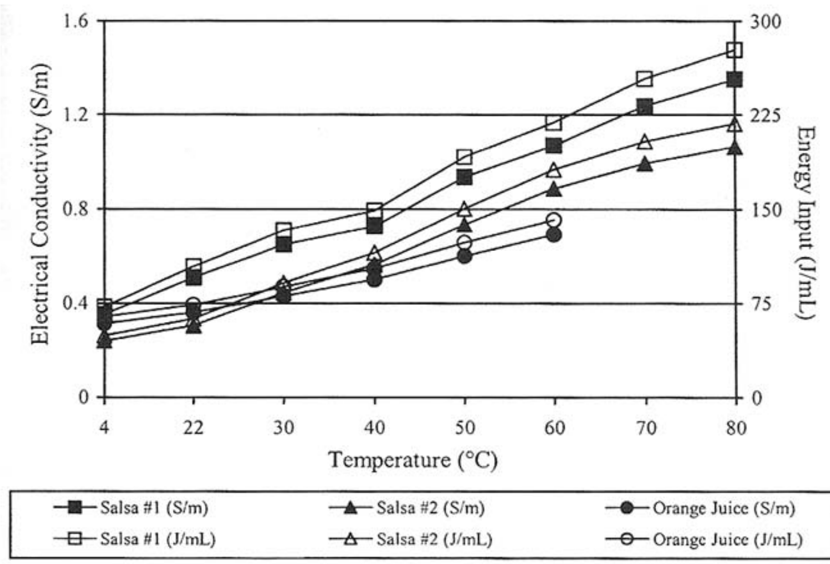

Figure 14.1 Electrical conductivity and calculated energy input per pair of chambers vs. temperature for salsa.

With an increase in temperature, there is an increase in the electrical conductivity, and the energy input is directly proportional to the electrical conductivity of the food (Figure 14.1). Since the only variable in the calculation of energy input is the electrical conductivity, this was expected. The electrical conductivity values for the salsas before salt was added are both about two times greater than for the orange juice. Currently, orange juice is PEF processed at 30°C. At this temperature, the energy input is approximately 87 J/mL per pair of chambers. When the salsa products are processed at 40°C, the energy consumption per pair of chambers would be 148 J/mL for salsa #1 and 115 J/mL for salsa #2.

The change in temperature during treatment is directly proportional to the electrical conductivity of the product (Figure 14.2). If salsa #2 enters the first pair of chambers at 40°C, there will be a maximum of 27°C increase in the product temperature when it exits. This temperature increase needs to be carefully controlled because as the temperature increases, the electrical conductivity and energy consumption also increase. By using a cooling heat exchanger between each pair of chambers, this temperature change is kept to a minimum.

The apparent viscosity of both salsa reformulations decreases with an increase in temperature (Figure 14.3). These products are pseudoplastic, which means that the viscosity decreases with an increase in shear rate. The viscosity was measured at very low shear rates compared to what the product will

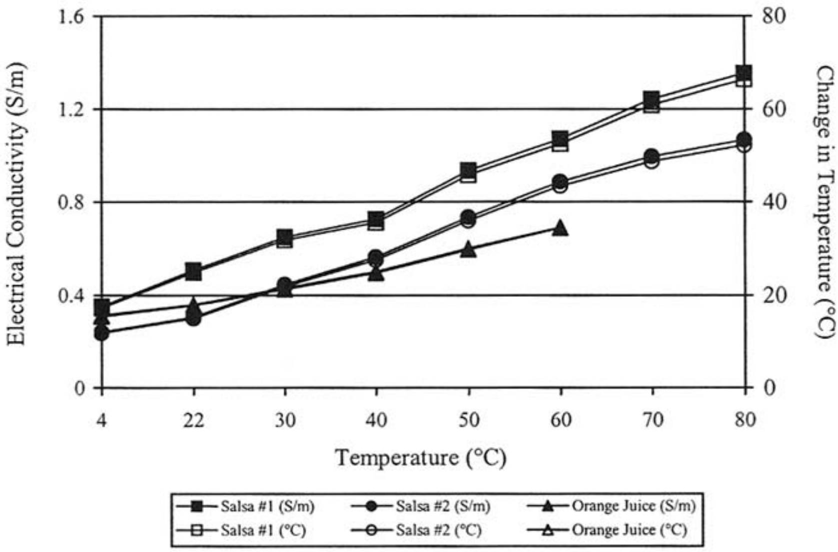

Figure 14.2 Electrical conductivity and calculated energy input per pair of chambers vs. temperature for salsa.

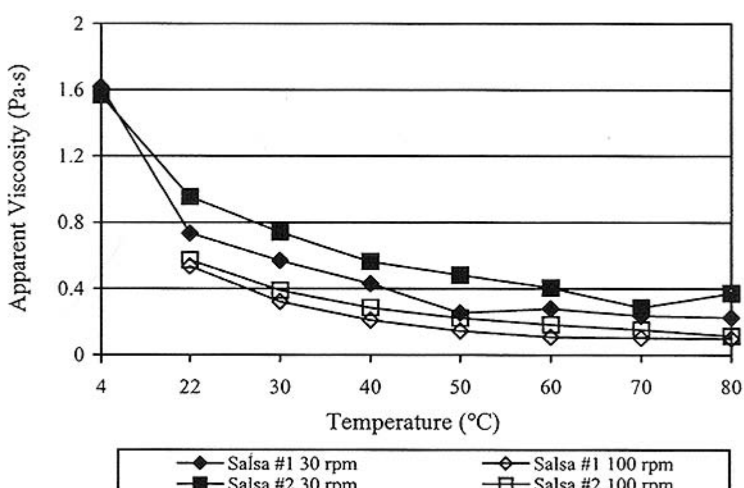

Figure 14.3 Apparent viscosity vs. temperature for salsa.

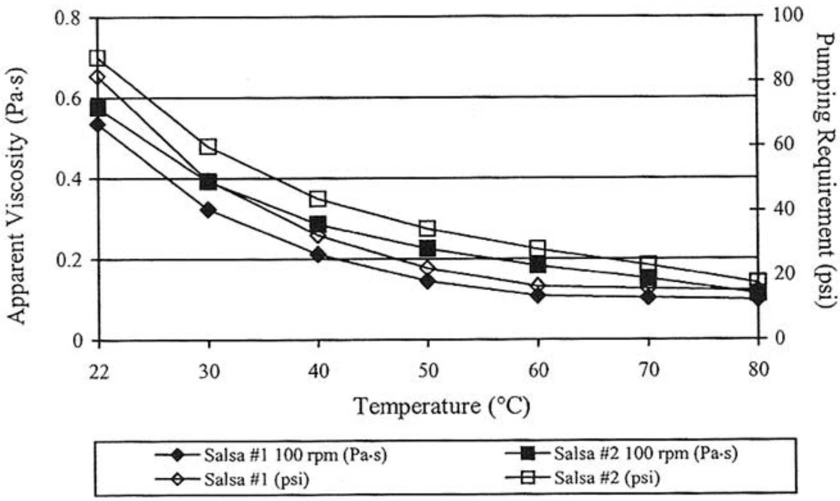

Figure 14.4 Apparent viscosity and calculated pumping requirement for the chamber vs. temperature for salsa.

encounter during processing. If the product is flowing at a very high rate of shear during treatment, the viscosity will be reduced even further. As the temperature increases, the viscosity and pumping requirements decrease (Figure 14.4). This is important because of the limitation of the fluid handling system. We suggest that the pressure not exceed 100 psi for the entire fluid handling system if a pump with maximal capacity of 150 psi is used. Since the treatment chamber has the smallest inner diameter of all of the tubing of the fluid handling system, the greatest pressure drop will be seen through this section.

CHEESE SAUCE

Removing all of the salt from the cheese sauce, including the sodium citrate and salt added for flavor, will reduce the electrical conductivity. However, this creates a new problem with the product viscosity, since sodium citrate is added to aid emulsification, and to enhance the texture of the product. With an increase in the amount of sodium citrate, there is an increase in the electrical conductivity of the cheese sauce (Figure 14.5). The electrical conductivity of the cheese sauce with 0.5% sodium citrate was less than the electrical conductivity of the orange juice. Since it is known that the energy input is directly proportional to the electrical conductivity of the food, this indicates that less energy will be required to process the cheese sauce than to process the orange juice.

As the input temperature is increased, the temperature change is increased (Figure 14.6). The change in temperature during treatment is proportional to

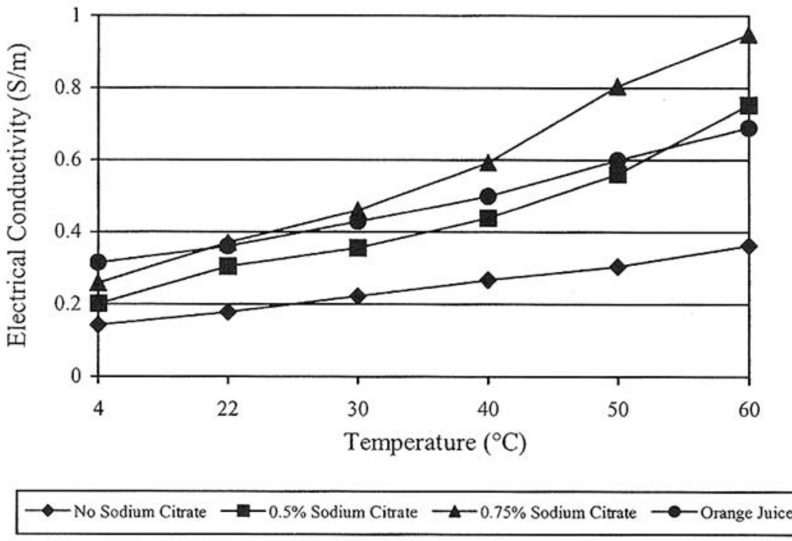

Figure 14.5 Electrical conductivity vs. temperature for cheese sauce.

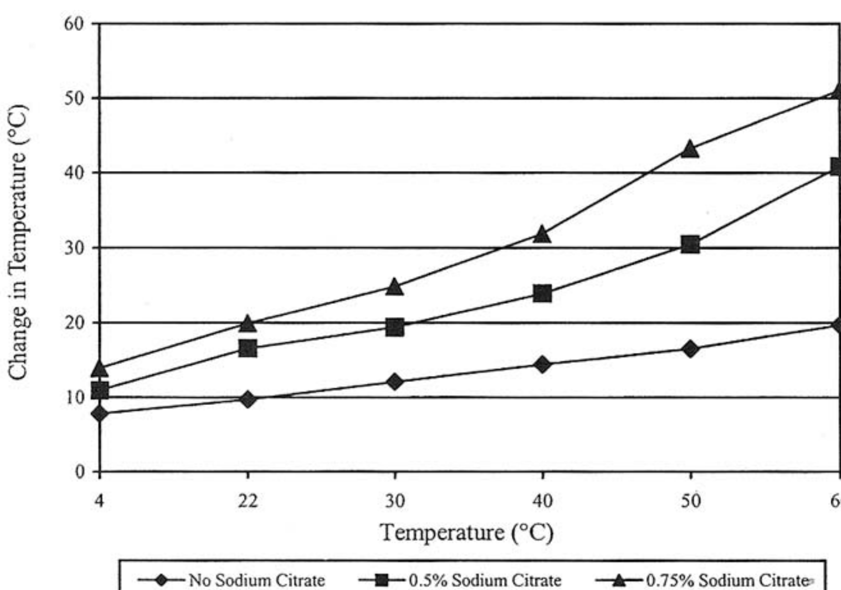

Figure 14.6 Calculated change in temperature per pair of chambers vs. input temperature for cheese sauce.

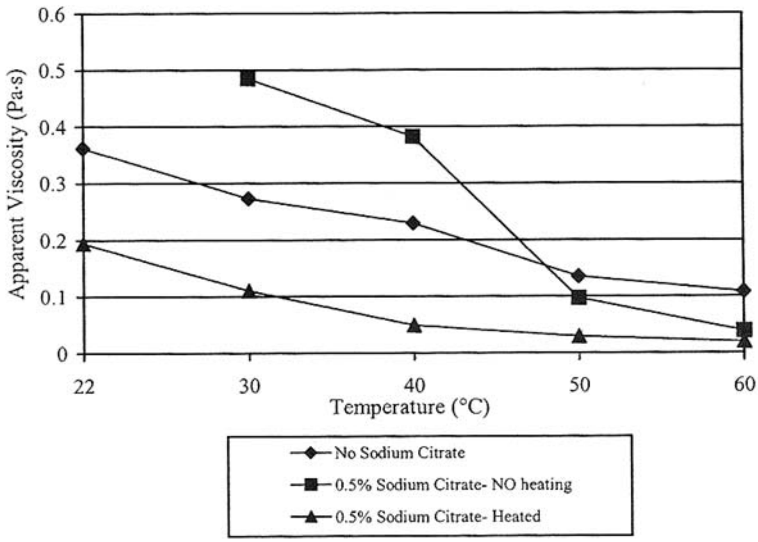

Figure 14.7 Apparent viscosity at 375 s^{-1} shear rate for cheese sauce vs. temperature.

the electrical conductivity of the product, and can be kept to a minimum with the use of a cooling heat exchanger.

The 0.5% sodium citrate cheese sauce that was heated to 60°C and cooled before measuring had the lowest apparent viscosity (Figure 14.7). Also, at 50°C the viscosity dropped rapidly for the products containing sodium citrate, and then changed very little at 60°C. This indicates that 50°C would be the optimum treatment temperature in terms of viscosity. When measured at three rates of shear, the cheese sauce exhibited pseudoplastic properties (Figure 14.8). This indicates that as the product moves faster through the tubing, it will encounter more shear rate, and the viscosity will be further reduced. As the viscosity is decreased, the pressure differential is also decreased (Figure 14.9). At 50°C the pressure differential is approximately 5 psi in the treatment chamber, which has the smallest inner diameter of the entire fluid handling system.

CONCLUSIONS AND RECOMMENDATIONS

In order to have successful PEF treatment of products with high electrical conductivity and viscosity, a combination of process parameter adjustment and product physical property adjustment is necessary. Also, careful control of temperature during treatment is necessary to assure that the desired dosage levels are achieved.

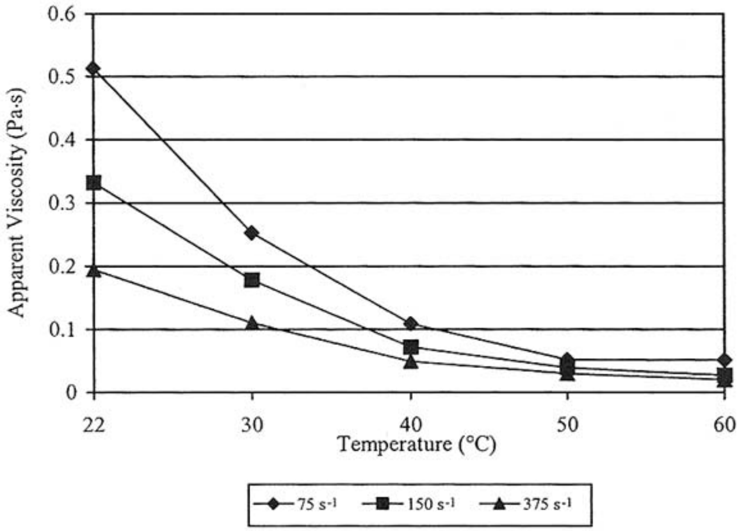

Figure 14.8 Apparent viscosity at increasing shear rate vs. temperature for cheese sauce containing 0.5% sodium citrate.

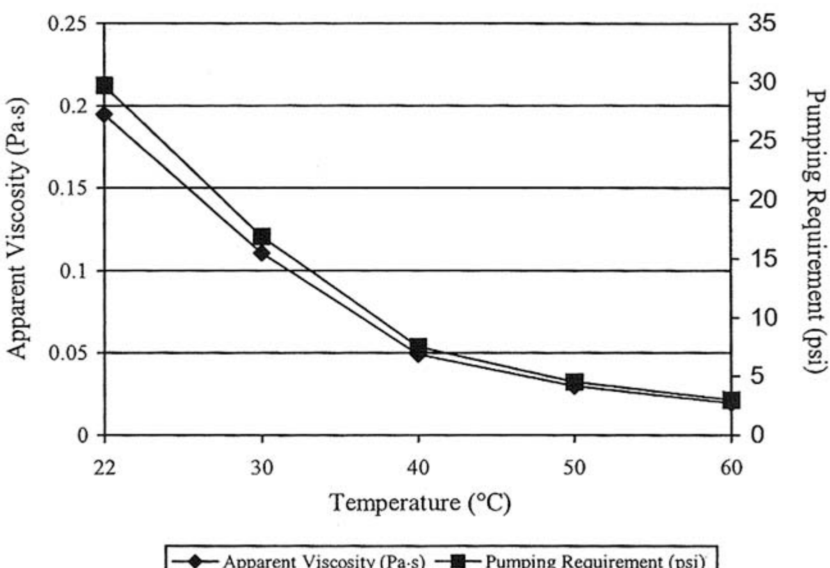

Figure 14.9 Apparent viscosity and calculated pumping requirement vs. temperature for cheese sauce with 0.5% sodium citrate.

We recommend that for PEF processing, salsa #2 be prepared without salt and blended until the particles are less than 1/8 inch in size, if a chamber size of 0.635 cm ID (½ in.) is used. In order to be most efficient in terms of pumping requirements and energy input, it is recommended that processing begin at 40°C. At 40°C the energy input needed to achieve a 32 kV/cm electric field strength is 115 J/mL, and the temperature change is 30°C per pair of treatment chambers. Also, the pumping requirement is 30 psi, which is approximately 30% of the total pumping limits.

We recommend that a cheese sauce containing 0.5% sodium citrate be prepared and heated to 60°C before PEF processing. Processing at 50°C is recommended for efficiency. The energy input needed to achieve a 32 kV/cm electric field strength is 114 J/mL, and the temperature change is 30°C per pair of chambers. The pumping requirement for the treatment chamber is 5 psi, which is 5% of the total pumping limitations.

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