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Research Article

EFFECT OF OHMIC HEATING AND LYE-SALT CONCENTRATIONS ON TOTAL SOLUBLE SOLIDS AND TITRABLE ACIDITY OF TOMATO PUREE

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Abstract: The study was initiated with the objective of evaluating the effect of ohmic heating and lye (NaOH, KOH)-salt (NaCl) concentrations on the quality parameters such as total soluble solid (TSS) and titrable acidity of ohmically heated tomato puree. Ohmic heating works on the principle of electroporation due to the resistivity of the product internal heat generated and therefore conversion of electrical energy into heat happened. The parameters such as field strength and lye- salt concentration which were found considerably effect on titrable acidity and total soluble solids. The full factorial statistical design was used to analyze the dependent parameters. The independent variables selected for the study were lye concentrations (0.1, 0.2, 0.3, and 0.4%), salt concentrations (0.1, 0.2, 0.3 and 0.4%) and applied electric field strength (928.57, 1071.42 and 1214.28 V/m). The results of the study show that the acidity values were all within a certain range, approximately 0.43% to 0.31% for 0.1%NaOH at 928.57 V/m and 0.4%NaCl at 1214.28 V/m treatments, best condition of treatment was 0.1% NaOH with 928.57 V/m. Ohmic heating keeps the TSS of tomato puree well within the acceptable range. The optimal values of independent variables in terms of lye or salt and electric field strength for TSS0.3%NaOH/1071.42V/m, 0.3%NaOH/928.57V/m, 0.2%NaOH/1071.42V/m, 0.2%NaOH/928.57V/m, 0.1%NaOH/1071.42, 0.1% NaOH/928.57V/m. It can be concluded that ohmic heating minimize the losses of acidity and TSS of tomato puree. No previous work dealing with the comparison of the impact of ohmic heating processing acidity and TSS of tomato puree has been found therefore this study aims to address this deficiency.

Keywords: Ohmic heating, Lye and salt concentrations, Field strength, TSS and titrable acidity

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Introduction

India's agriculture is composed of various crops which include cereals, pulses, oilseeds, cash crops, vegetables and also non-food items as tea, coffee, jute, cotton etc. India is a fastest growing exporter of agriculture products and also top producer of fruits and vegetables in the world. Tomato (*Solanum lycopersicum*) belongs to the family *Solanaceae*. Tomato is subjected as major agriculture product rated fourth most commonly crop in world [1] and world's largest vegetable crop after potato and sweet potato [2]. Tomatoes arrive to the consumer in two practices: fresh market tomato and processed tomato. The fresh market tomatoes are whole tomatoes without any processing that are sent directly to the consumer from the field. The processed tomato is any, tomato based products such as jam, Jelly, soup, chutney etc. in which the tomato goes through various unit operations which include cleaning, peeling, blanching etc [3]. Approximate 85 % tomatoes produced in processed form including juice, purees, pastes, sauces, soup, salsa and canned tomatoes required peel removal [4]. The internal resistance by conduction results in very heterogonous treatment and the notable loss of product quality [5-7]. To overcome these problems; substitute technologies using electrical energy directly in the food processing have attracted interest in the food industry in recent decades. The principle of ohmic heating is dissipation of electrical energy into heat which results in internal energy generation. Ohmic heating is also termed as 'joule heating or electro heating'. This is more recent development in which an alternating electric current is passed through a food, and electric resistance of the food causes the power to be translated directly into heat [8]. Ohmic heating yields better products, clearly superior in quality than those processed by conventional heating [9,10]. Its advantages compared to conventional heating also include the more uniform and faster heating, higher yield and higher retention of nutritional value of food [11]. This is mainly due to its capability to heat materials rapidly and homogeneously leading to a less violent thermal treatment. The advantages of using ohmic heating as a food processing method are many [12]. The food product is heated rapidly as the rate of heating is only relevant to the electrical resistance of the particular food and not limited by the heat transfer coefficient. Based on these characteristics, the energy conservation efficiencies may be greater than 90%. Two important quality attributes of processing tomatoes are titrable acidity and total soluble solids. A strong positive relationship is obtained between skilled panel response to sweetness and reducing sugar or total soluble solids content [13]. The sour sensitivity in tomato is predictable mainly to citric and malic acids. Sourness' strictly correlates with titrable acidity [14]. Decline in the acidity level has been associated with quality loss during tomato post-harvest storage and together with soluble solids content, can influence consumer's acceptability. Keeping all above cited issue in mind, the present work has been undertaken with the objective to evaluate and compare the effects of ohmic heat treatment and lye-salt concentrations on titrable acidity and total soluble solids in ohmically heated tomato puree.

Materials and Methods

This study related with the materials and methodologies which were adopted during the present research work. Experiments were conducted to study the effect of ohmic heating on titrable acidity and total soluble solids of ohmically heated tomato puree [15-20].

Independent parameters and their levels were finalized based on the observations and concluded result obtained from preliminary experiments.

Experimental location

The experiments were conducted in the laboratory of Department of Post Harvest Process and Food Engineering, College of Technology and the laboratory of Department of Chemistry, College of Basic Sciences and Humanities, G.B.Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar (Uttarakhand)

Raw materials

Fresh, fully matured, red in colored cherry type tomatoes of variety Pant Bahar were selected as the raw material for ohmic heating. Cherry type tomato commonly known as *Solanum lycopersicum* was procured from vegetable research centre (VRC) of G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. The tomatoes were washed in clean water to remove dust or other foreign materials on it and then wiped with cotton cloth.

Preliminary experiment

Preliminary experiments were carried out based on the past research work and reviews cited on different methods of tomato puree heating, salt or lye solution at various concentrations and different voltage gradients. On the basis of preliminary experiments and reviewed study, the values for independent variables (voltage gradient, salt concentration levels, lye concentration levels) were finalized.

Independent parameters of the experiment

Standard ohmic heating variables (Ngasri and Sastry, 2014) consisting of salt concentrations and lye concentrations, voltage gradient was selected. The levels of the variables have been chosen based on preliminary runs and literature reviewed. Certain parameters like number of tomato (one), variety of tomato (pant bahar), and weight of sample (approximately 60g) were fixed for entire experiments, decided on the basis of trial runs. [Table-2] shows the value of levels of each of these variables.

Preparation of salt and lye concentrations solution

Salt and lye concentrations were prepared on the basis of weight per volume percentage. For 0.1% of salt concentration dissolved 0.1g of salt in 100 ml of distilled water similarly for 0.2%, 0.3% and 0.4% dissolved 0.2g, 0.3g and 0.4g of salt in 100 ml of distilled water respectively. For 0.1, 0.2, 0.3 and 0.4 % of Lye concentrations (NaOH and KOH) dissolved 0.1, 0.2, 0.3 and 0.4 g of lye powder in 100ml of distilled water respectively.

Experimental Methodology

The ohmic heating chamber is very important for efficient heating employed a circular geometry was constructed by PVC pipes of 7 cm diameter, 16.8 cm in length and 2 mm in thickness. The electrodes have well grade, non-corrosive and chemically inert made from stainless steel. The distance between two electrodes has kept 14 cm to pass maximum voltage gradient of 16.5 V/cm from Indian household electric supply of 230 V. Nuts and bolts made of stainless steel (SS) 316 are used for attaching the wire with the electrodes. Bestronics made digital temperature manager with stainless steel probe was used monitor the temperature inside the heating chamber. Teflon coated, J type thermocouple which can withstand a temperature of 0-600°C is placed at the geometric centre of the ohmic heating cylinder to control the temperature during ohmic heating.

Analytical techniques for quality parameter

Standard methods for measurement of quality attributes were followed for entire experiments. Some of these methods were modified as per literature review to provide better, more precise quality estimation. Analytical grade chemicals and glass wares (borosil make) were utilized for conducting the experiments.

Total Soluble Solids

The refractometer is used to measure the total soluble solid content or refractive index of fruits. The determination of TSS by refractometer is based on the capacity of sugars to deviate light. After peel removed whole tomato was blended in a domestic blender. A single drop of the blend was placed on the prism of hand refractometer (0-32 ºBrix at 20º C). The refractometer was pointed towards a light source and ºbrix was read [15]. The hand refractometer is shown in [Fig-2].

Titrable Acidity

Titrable acidity was determined by standard method using visual titration method [15]. It is based on acid base titration. Indicator does not give any color in acidic medium indicator give pink color and this give end point.

Sample preparation and measurement

10 g of blended ohmically heated tomato puree was taken. 90 ml of distilled water was added and blended for 2 minute and filtered. 5 ml of the filtrate was transferred into a 100 ml conical flask. 10 ml of distilled water and 4-5 drop of phenolphthalein indicator was added into the solution. Titration was done against 0.1N NaOH added was recorded. The results were expressed (*e.g.* as milliequivalent per 100 g sample) in terms of the principal acid present.

$$Titrable\ acidity(\%) = \frac{Titre \times Normality\ of\ alkali \times volume\ made\ up \times equivalent\ weight\ of\ acidity}{volume\ of\ sample \times volume\ of\ aliquot \times 1000}$$

Fig-1 Ohmically heated tomatos puree samples

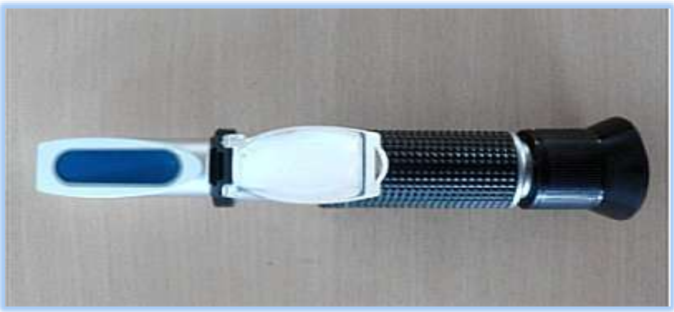

Fig-2 Hand held refractometer

Table-1 *Values for Independent variables*

SN	Independent Parameter	Levels	Values
1	Lye solutions (NaOH, KOH), Salt solution (NaCl)	4,4 4	0.1%, 0.2%, 0.3% and 0.4%. 0.1%, 0.2% 0.3% and 0.4%
2	Applied field strength	3	1214.28 V/m, 1071.42 V/m and 928.57 V/m

Table-2 *Effect of electric field strengths and concentrations on titratable acidity*

SN	Field strength(V/m)	Concentration (%,w/v)	TA (%) NaOH	TA (%) KOH	TA (%) NaCl
1	1214.28	0.1	0.414±0.006	0.402±0.006	0.387±0.018
2		0.2	0.402±0.006	0.354±0.005	0.357±0.023
3		0.3	0.385±0.010	0.346±0.021	0.354±0.021
4		0.4	0.368±0.008	0.322±0.022	0.318±0.010
5	1071.42	0.1	0.420±0.006	0.419±0.005	0.400±0.002
6		0.2	0.418±0.003	0.388±0.004	0.375±0.015
7		0.3	0.418±0.009	0.377±0.007	0.371±0.011
8		0.4	0.393±0.009	0.361±0.010	0.354±0.010
9	928.57	0.1	0.438±0.006	0.426±0.006	0.422±0.014
10		0.2	0.422±0.003	0.414±0.006	0.3989±0.011
11		0.3	0.420±0.000	0.392±0.003	0.379±0.002
12		0.4	0.411±0.006	0.378±0.006	0.366±0.001

Table-3 *Effect of electric field strengths and concentrations on total soluble solid*

SN	Field strength(V/m)	Concentration (%,w/v)	TA (%) NaOH	TA (%) KOH	TA (%) NaCl
1	1214.28	0.1	0.414±0.006	0.402±0.006	0.387±0.018
2		0.2	0.402±0.006	0.354±0.005	0.357±0.023
3		0.3	0.385±0.010	0.346±0.021	0.354±0.021
4		0.4	0.368±0.008	0.322±0.022	0.318±0.010
5	1071.42	0.1	0.420±0.006	0.419±0.005	0.400±0.002
6		0.2	0.418±0.003	0.388±0.004	0.375±0.015
7		0.3	0.418±0.009	0.377±0.007	0.371±0.011
8		0.4	0.393±0.009	0.361±0.010	0.354±0.010
9	928.57	0.1	0.438±0.006	0.426±0.006	0.422±0.014
10		0.2	0.422±0.003	0.414±0.006	0.3989±0.011
11		0.3	0.420±0.000	0.392±0.003	0.379±0.002
12		0.4	0.411±0.006	0.378±0.006	0.366±0.001

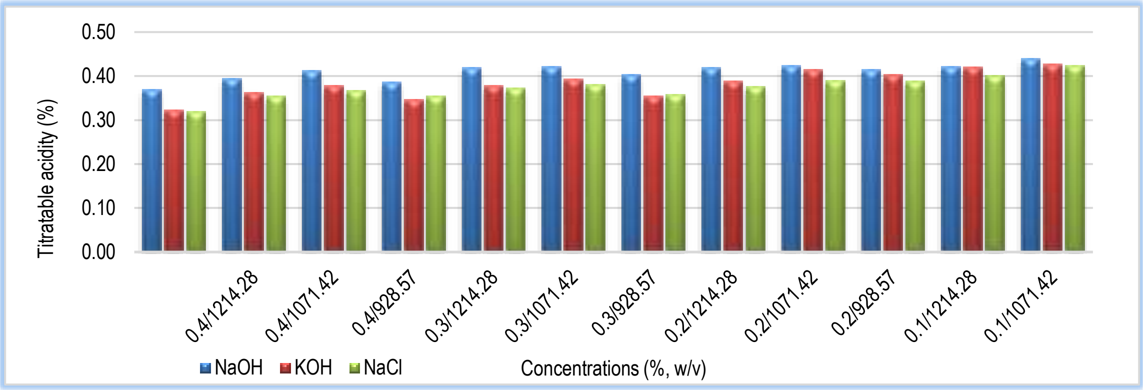

Fig-3 Comparative effect of concentrations and field strengths on titratable acidity

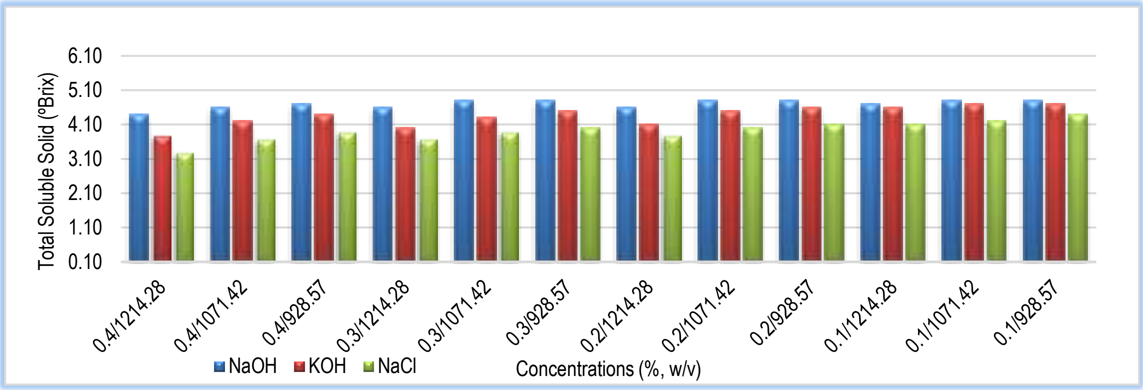

Fig-4 Comparative effect of field strengths and concentrations on total soluble solid

Result and Discussion

Effect of electric field strengths and concentrations on titratable acidity

The experiments were planned keeping field strength, lye (NaOH and KOH) and salt (NaCl) concentrations as the independent parameters. The influence of various factors was analyzed using a statistical technique *i.e*. Analysis of Variance (ANOVA) by SAS (Statistical Analysis System) version 9.1. The ANOVA of response breaks down the total variance of response and indicates whether the influence of a particular factor is statistically significant or not. The significance of any factor was judged by comparing the corresponding Fcal-value in the ANOVA (Fcal) table with Ftab-value. The results obtained in this study are presented [Table-1] and [Table-2]. Experimental data are presented in [Table-2] shows that observed value of titratable acidity under different field strengths (1214.28 V/m, 1071.42 V/m, and 928.57 V/m) and (0.1%, 0.2%, 0.3% and 0.4%) concentrations of NaOH, KOH and NaCl respectively. Titratable acidity of tomato puree varied from 0.36% citric acid to 0.43% citric acid. Lowest value of titratable acidity was observed for 0.4% NaOH at 1214.28V/m field strength; whereas the highest was observed for 0.1% NaOH at 928.57V/m field strength. The data were tabulated as average of the 3 replicates ± standard deviation (SD). The titratable acidity of ohmically heated tomato puree under various concentrations for KOH is also shown in [Table-2] Obtained titratable acidity values were varied from 0.32% citric acid to 0.42% citric acid. The lower and higher limit value of titratable acidity recorded under the conditions of 0.4% KOH/1214.28 V/m and 0.1% KOH/ 928.57V/m respectively. The temperature values were varied from 79 ºC to 93.3 ºC for 0.1% KOH/ 928.57 V/m and 0.4% KOH/ 1214.28 V/m respectively. [Table-2] also shows the observed value of titratable acidity for 0.1% to 0.4% NaCl concentrations at different field strengths. Minimum value of titratable acidity (0.31%) was recorded for 0.4% NaCl at 1214.28V/m field strength while maximum value of titratable acidity (0.42%) for 0.1%NaCl at 928.57V/m field strength were observed. The minimum and maximum temperature values were for 78ºC to 93.3ºC for solution NaCl concentration respectively. Analysis of variance (ANOVA) was performed to observe the significant effect of process variables (field strength and NaOH, KOH, NaCl concentrations) on titratable acidity of tomato puree. It was indicated by ANOVA that field strength and concentration play major role influencing the titratable acidity of tomato puree under various conditions. As the Fcal values are greater than Ftab at 1% and 5% level of significance respectively. ANOVA also shows that field strengths (Fcal=86.92**) NaOH concentrations (Fcal= 4.65**) and their interaction (Fcal= 14.88**) had significant effect on titratable acidity. Similarly, ANOVA was carried out to check the adequacy of the independent variables (field strength and KOH/NaCl concentration). The field strength (A) Fcal value of 116.70 and KOH concentration (B) Fcal value 4.45 indicated that the significant effect. The effect of independent variables was found highly significant at 1% and 5% level of significance (Ftab>Fcal). Fcal value for interactive term was found 11.36 (greater than Ftab 3.67) at 1% level of significance. The field strength (A) Fcal value of 94.38 and NaCl concentration (B) Fcal value 10.51 indicated that the highly significant effect. The effect of independent variables was found highly significant at 1% level of significance (Ftab>Fcal). The Fcal value of field strength (94.38) higher than Ftab value (5.61). Fcal value for NaCl concentrations and their interactive term was found 10.51 and 8.27 (greater than Ftab 4.72 and 3.67) at 1% level of significance. It concluded that the field strength, NaCl concentration and their interaction had significantly effect on titratable acidity. A comparative study of effect of lye-salt concentrations and field strengths on titratable acidity is shown in [Fig-3]. The treated tomato puree with higher concentration of NaCl (0.4%) at high field strength gave lowest value of titratable acidity (0.31%) whereas the titratable acidity was found highest at lower concentration of NaOH (0.1%) at low field strength (928.57V/m). Hence concluded that the decreasing the concentration of solution titratable acidity content increased. Similar values were reported in a study by Garcia and Barrett (2006).

Effect of electric field strength and concentration on total soluble solid

The total soluble solid (TSS) values of ohmically heated tomato puree were recorded by using hand refractometer. [Table-3] shows the effect of electric field strengths and NaOH concentrations, effect of electric field strengths and KOH concentrations and effect of electric field strengths and NaCl concentrations on total soluble solid respectively. It is observed from the table that the values of total soluble solid (TSS) varied from 3.3 ºBrix to 4.8 ºBrix for different treatments. It is observed from the table that the values of total soluble solid varied from 4.4 ºBrix to 4.8 ºBrix for NaOH concentrations. The maximum value (4.8 ºBrix) of total soluble solid were found for the six treated samples (0.3%NaOH/1071.42V/m, 0.3%NaOH/928.57V/m, 0.2%NaOH/1071.42V/m, 0.2%NaOH/928.57V/m, 0.1%NaOH/1071.42, 0.1%NaOH/928.57v/m) and minimum value (4.4 ºBrix) for 0.4%NaOH/1214.28V/m respectively. The data were tabulated as average of the 3 replicates ± standard deviation (SD). The observed total soluble solid was found in the range of 3.8 ºBrix (minimum value) and 4.7 ºBrix (maximum value) for 0.4% KOH at 1214.28 V/m and 0.1% KOH at 1071.42 V/m respectively. Whereas the obtained values total soluble solid (TSS) values under the various concentrations of NaCl and Field strengths is also showed in [Table-3]. The higher (4.4 ºBrix) and lower values (3.3 ºBrix) of total soluble solid were recorded under the conditions of 0.1% NaCl at 928.57 V/m and 0.4% NaCl at 1214.28 V/m respectively. comparative study of effect of lye-salt concentrations and field strengths on total soluble solid (TSS) is shown in [Fig-4]. The ohmically heated tomato puree with higher concentration (0.4%) of NaCl at high field strength (1214.28V/m) gave lowest value of total soluble solid (3.3 ºBrix) as compared to KOH (3.8 ºBrix) and NaOH (4.4 ºBrix) concentrations. Analysis of variance for treatment variables as field strength (factor A) and NaOH, KOH and NaCl concentrations (factor B) and their interaction (factor A x factor B) were recorded. The analysis was done by means of Fisher's –test. Ftab for field strengths, NaOH, KOH and NaCl concentrations and their interactions were 5.61; 4.72; 4.72; 4.72 and 3.67 respectively. The Fcal values for field strength, NaOH concentrations and their interactions were 212.10; 14.45 and 65.87 at 1% level of significance respectively. The Fcal value for field strength, NaOH concentrations and their interactions were found greater than Ftab. It was indicated that the independent parameters play major role on the total soluble solid. Similarly, Fcal values for field strength, KOH concentrations, their interactions and field strength, NaCl concentrations, their interactions were 1570.4, 119.24, 220.16 and 11164.71; 131.61, 90.31 at 1% level of significance respectively. The Fcal-values were found greater than tabulated F-values. The Fcal of NaCl concentration had found much greater than Ftab since NaCl had play major role on total soluble solid. It was indicated that the independent parameters play major role on the total soluble solid. With respect to TSS the most significant changes were observed in NaCl concentrations at 1214.28V/m field strength which decreased significant from 4.4 ºBrix to 3.3 ºBrix.

Conclusion

On the basis of the experimental results and data analysis we concluded that once the temperature rise to the 60ºC wax melting could occur permitting allowing a pathway to electric current. This would tend to increase the rate of various cell walls (epicarp, pericarp, hemicelluloses) breakdowns. When the lye- salt concentration of the medium increases, the heat generation in the medium would be quicker due to higher electrical conductivity. The acidity values were all within a certain range, approximately 0.43% to 0.31 % for 0.1 % NaOH at 928.57 V/m and 0.4 % NaCl at 1214.28 V/m treatments, best conditions of ohmic treatment was 0.1 % NaOH with 928.57 V/m. Ohmic heating keeps the TSS of tomato puree well within the acceptable range. The optimal values of independent variables in terms of lye or salt and electric field strength for TSS 0.3% NaOH/1071.42V/m, 0.3% NaOH/928.57V/m, 0.2% NaOH/1071.42V/m, 0.2% NaOH/928.57V/m, 0.1% NaOH/1071.42, 0.1% NaOH/928.57v/m.

Application of research: It can be hypothesized that ohmic heating will lead to innovation in the development of a novel technology for treatment of tomato puree and that have potential to eliminate the limitations of existing commercialized methods. As a benefit, improved product yield, and quality of processed tomato products will result.

Research Category: Post-Harvest Process and Food Engineering

Abbreviations: TSS: Total soluble solids, NaOH: Sodium hydroxide

KOH: Potassium hydroxide, NaCl: Sodium chloride
W/V: Weight per volume basis

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Study area / Sample Collection: Post-Harvest Process and Food Engineering, G. B. Pant University of Agriculture and Technology, Pantnagar, 263153, Uttarakhand

Cultivar / Variety name: Tomato (*Solanum lycopersicum*)

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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