Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2320-7051.2898

ISSN: 2320 – 7051

Int. J. Pure App. Biosci. **5 (5):** 1099-1107 (2017)

Research Article

International Journal of Pure & Applied Bioscience

OPEN ACCESS

Feasibility Study of a Self-Heating Container for Cooking of Noodles using Exothermic Reaction

Rupesh P. Datir[1*], Anant V. Dhotre[1], Prashant G. Wasnik[1] and Gajanan P. Deshmukh[2]

[1]College of Dairy Technology, Warud (Pusad), Maharashtra Animal and Fishery Sciences University, Nagpur

[2]National Dairy Research Institute, SRS, ICAR-NDRI, Bangalore

*Corresponding Author E-mail: rupeshdatir@gmail.com

Received: 24.04.2017 | Revised: 30.05.2017 | Accepted: 8.06.2017

ABSTRACT

Present study was planned to test the feasibility of developing self-heating container for Noodles by providing exothermic reactants in a double sectional container whose heat of reaction would cook up the noodles placed in other section when their reaction is triggered. The cooking parameter viz., dry noodles:water ratio, cooking time, temperature, heat requirement and heat generation parameters viz., type and proportions of exothermic reactants, maximum temperature, rate of heating, overall heat transfer coefficient, etc. were evaluated. The dry noodles to cooking water ratio of 1:2.0 was found best for sensory acceptability. The second best ratio was 1:2.5. The anhydrous Calcium Oxide (CaO) and Water (H_2O) were selected as the exothermic reactants. Among their several combinations, the combination of 150 g CaO and 75 ml H_2O gave best result in terms of heating rate and maximum temperature. The container design having product bowl atop the container with its bottom serving as the heat transfer surface was found better. The proportion could effectively cook 60 g noodles and 120 ml water in less time. The product such cooked was acceptable but inferior to conventionally cooked noodles taken as control. Further scope for controlling reaction, reducing weight and improving heat recovery exists.

Key word: *Self heating, Noodle, Calcium Oxide, Ready-to-Eat, Exothermic.*

INTRODUCTION

The food choice and diet patterns of Indian consumers have witnessed marginal change in recent past. The preference has been shifted from traditional home cooked foods to more convenient, ready-to-cook or ready-to-eat foods. Number of food products that need no sluicing and much preparation before cooking such as noodles has evolved. Noodles are one of the most popular foods in the Indian market. According to a recent report by research-based global management consulting firm TechSci Research, India's ready-to-eat (RTE) food market is projected to grow at a compound annual growth rate (CAGR) of around 22% between 2014 and 2019. The market is anticipated to grow on account of increasing working population, growing per capita disposable income, rising per capita expenditure on prepared food, increasing middle-class and affluent consumers (techsciresearch.com).

Cite this article: Datir, R.P., Dhotre, A.V., Wasnik, P.G. and Deshmukh, G.P., Feasibility Study of a Self-Heating Container for Cooking of Noodles using Exothermic Reaction, *Int. J. Pure App. Biosci.* **5(5):** 1099-1107 (2017). doi: http://dx.doi.org/10.18782/2320-7051.2898

Noodles need short but inevitable cooking before consumption, which too is inconvenient or impossible in certain situations. Hence, present study was planned to test the feasibility of embedding cooking facility in the package itself so that the cooking can be done as and when required. It was planned to provide exothermic reactants in a double sectional container whose heat of reaction would cook up the noodles placed in other section whenever their reaction is triggered.

MATERIAL AND METHODS

Standardization of process parameters for cooking Noodles: A well laid cooking process is one of the requisites for in container cooking. It was essential to identify best cooking parameters before designing the self-heating container/process. The important parameter such as the amount of water added to noodles for cooking, the cooking temperature and cooking time that are decisive in sensory acceptance of the product were decided as follows.

Dry noodles to cooking water ratio: The ratio of dry noodles to the cooking water to be taken for the study was determined through preliminary trials followed by the sensory evaluation for the overall acceptability. Several proportions of *Dry noodle: Cooking water viz.,* 1:1, 1:1.5, 1:2.0, 1:2.5 and 1:3.0 as shown quantitatively in Table 1 were tried.

Cooking temperature: Preliminary trials were conducted to decide the optimum cooking temperature for the noodles. Noodles were cooked at five different temperatures in the water bath and were subjected to sensory evaluation to arrive at the optimum cooking temperature to be used during the study.

Cooking heat requirement: The cooking heat requirement i.e. the heat required for the cooking of noodles, as crucial for estimating the quantities of exothermic reactants, was determined analytically from the composition of the noodles and required cooking temperatures.

Heat requirement for the cooking of the experimental sample was calculated as follows:

$$Q_{total} = Q_{Water} + Q_{Product}$$
$$= \{M_w \times C_{pw}(T_{Cooking} - T_{initial})\} + \{M_n \times C_{pn}(T_{Cooking} - T_{initial})\}$$

Where; M_w is the mass of cooking water, C_{pw} is the specific heat of cooking water, $T_{cooking}$ is the cooking temperature, $T_{initial}$ is the initial temperature, M_n is the mass of noodles, and $C_{pn}$is the specific heat of noodles.

The value of the specific heat for noodles C_{pn} was estimated using Choi and Okos model (1983) under:

$$C_{pn} = \sum_{i=1}^{5} X_i \times C_{pi}$$
$$C_{pn} = X_w \times C_{pw} + X_c \times C_{pc} + X_p \times C_{pp} + X_f \times C_{pf} + X_a \times C_{pa}$$

Where; $X_{W,}$ $X_{P,}$ X_F, X_C and X_A are the mass fractions of Water, Protein, Fat, Carbohydrate and Ash contents of the product and the $C_{pw,}$ $C_{pc,}$ $C_{pp,}$ C_{pf} and C_{pa} are the respective values of specific heats of the individual food constituents. The values of specific heats of these individual food constituents were calculated as functions of temperature using the following relations.

$$C_{pw} = 4.1762 - 9.0864 \times 10^{-5}T + 5.4731 \times 10^{-6}T^2$$
$$C_{pc} = 1.5488 + 1.9625 \times 10^{-3}T - 5.9399 \times 10^{-6}T^2$$
$$C_{pp} = 2.0082 + 1.2089 \times 10^{-3}T - 1.3129 \times 10^{-6}T^2$$
$$C_{pf} = 1.9842 + 1.4733 \times 10^{-3}T - 4.8008 \times 10^{-6}T^2$$
$$C_{pa} = 1.0926 + 1.8896 \times 10^{-3}T - 3.6817 \times 10^{-6}T^2$$

The empirical cooking heat requirement was also determined through preliminary trials. The mixture of dry noodles and cooking water was cooked in a metal container in water bath maintained at 100 °C along with another identical container filled with water taken as reference. Assuming the heat gained by both containers as same, it was found using following equation,

$$\therefore \text{ Actual cooking heat requirement} = \{M_w \times C_{pw}(T_{final} - T_{initial})\} + \{M_v \times h_{fg}\}$$

Selection of reactants for heat generation

From the literature studied for various means of heat generations and exothermic reactants the Calcium Oxide and Water were selected as they are easily available, nontoxic, GRAS status (www.fda.gov) and cost effective.

Designing the self-heating container

Four different designs that could satisfactorily fulfill the requirements towards containing the product, containing the reactants, enable and sustain the heat transfer, etc. were worked out. Two of which were discarded on the basis of observations made during preliminary trials (out of the scope of this paper).

Optimization of the reactants (CaO and H_2O)

To optimize their proportion for efficiently heating 60 gm dry noodles along with 120 ml water following combinations of Calcium Oxide and Water were studied. (Table 2)

Statistical Analysis of the Experimental Data

The data which was to be used for primary screening of the selected variables was analyzed using the measures of variation. The data obtained during the final screening and the proportion optimization was analyzed using the Completely Randomized Block Design to know the best combination.

RESULTS AND DISCUSSION

Composition of the noodles: On the basis of chemical analysis, the major constituents of the noodles as required in the model for estimating heat requirements were calculated. The average composition is shown in table 3.

Dry noodles to cooking water ratio: Noodles cooked with different proportions of dry noodles and cooking water were subjected to sensory evaluation by the judges for overall acceptability on hedonic scale. The results obtained are tabulated in Table 4. As appears in the Table 4, the ratio 1:2 scored highest among other proportions i.e. cooking water in the proportion of twice the quantity of the dry noodles was adjudged best irrespective of the quantity of the dry noodles. The noodles prepared with the 1:1 proportion showed dry surface and some fragments adhering to the container surface were observed. The softness was lacking with clear indication of insufficient cooking water availability. In case of 1:1.5 proportion, the softness was improved with no sign of product adherence to the vessel but the dryness still persisted. The proportion 1:2.5, showed soft free strands of the product with some sings of free water at the bottom. The amount of free water further increased in case of 1:3 proportion to greater extent and product tasted flat. It may because of the taste maker remained in the free water as sediment. Consequently, the proportions 1:2 and 1:2.5

were retained for further study. The analytical and actual heat requirements for cooking were studied for these proportions only.

Cooking temperature: Among the five cooking temperatures, the preliminary trials followed by sensory evaluation indicated that a temperature of about 85 °C was essential for satisfactory cooking of the noodles. (The temperature about 90 °C was found the best but it had the problem of vaporization).

Cooking heat requirement: Initial temperature for the mixture was set 30 °C and final cooking temperature was 85 °C, hence the value of specific heat was taken at the average temperature of 57.5 °C. The results on analytical heat requirement and actual heat requirement for cooking different mixtures of dry noodles and cooking water are tabulated in Table 5 and Table 6 respectively.

Actual cooking heat requirement

Rate of rise in cooking temperature in container

In the container of selected design that is product bowl atop the container, the cooking process was monitored in terms of rise in temperature of the contents after the reaction has been triggered. Peak temperature achieved in the product bowl and rate of temperature rise were noted with all the 11 combinations of CaO and H_2O (treatments). The data obtained is represented in Table 7.

It can be seen from the Table 7 that rates of heat generation (i.e. temperature rise) were different in different combinations from the first minute. The temperatures received with all the treatments were significantly different than each other. The temperatures received in some of the treatments were more than twice of that received with other treatments.

During the first minute, T11 produced highest temperature (86.66°C) among all the treatments; it was followed by T8 with 81.00°C. Though second highest, the temperature produced by T8 was significantly lower that produced by T11. It was the only treatment that could surpass the standard cooking temperature of 85 °C (as identified in the preliminary trails) within 1 minute. Similar trend was observed for temperatures achieved in the second minute. T11 recorded highest temperature of 91.00°C which was significantly higher than next highest temperature of 87.66 °C recorded by T8. Thus, the T8 qualified the cooking temperature in second minute.

In third minute, temperature of T8 and T11 were almost same i.e. 88.333 °C and 88.666 °C respectively. Beside these T9 also produced an average temperature of 87.00 °C. The treatments T8, T9 and T11 were at par in the third minute. It indicated that if the cooking time is of 3 minutes, the T8, T9 and T11 would give statistically similar effects. Temperatures produced by both of them were at par and both were above the desirable cooking temperature of 85 ^{o}C.

During fourth minute T11 recorded highest temperature of 87.00 °C which was significantly different than all other treatments including T8, which gave a temperature of 82.66 °C. From this point onward continuous fall was recorded in the temperature produced by T8. From the fifth and sixth minutes the temperatures given by all the treatments decreased. It indicated that the rates of heat generation and/or transfer to the products decreased. It may be due to the reason that concentration of the reactants decreased while the losses through escape of vapour from reactant space, convection and radiation to atmosphere remained persistent.

The highest temperature of the array was recorded by T11 followed by T8 with statistically insignificant difference. Hence, both the combinations can be adjudged the best to accomplish cooking within 2 minutes. Considering 3 minutes cooking, the T9 would be an additional option. The T8 would still be most preferable as it weighs 25 g less than T9 and T11 reducing overall weight of the container without any compromise in the cooking temperatures.

Heat generation, transfer and recovery

The actual heat generation and heat transfer to the product space were evaluated using the heat uptake equation for all the treatments and the results are shown in Table 8.

Table 8 clearly indicates very less heat recovery, the highest being in case of T8. The possible reasons for low heat recovery may be (i) formation and leakage of vapours (ii) poor thermal conductivity of the CaO that might form layer on heat transfer surface and restricting the movement of water molecules. It was also observed that though the heat recovery for T11 was lower than T8, the heat received in the product space was almost the same. There is fair possibility of less heat generation than the theoretical heat of reaction due to many factors like purity of reactants, rate of hydration, incomplete hydration, etc.

Overall heat transfer coefficients

The overall heat transfer coefficients obtained in the study are displayed in Fig. 2. Over the complete range of the various combinations of CaO and H_2O, the U-values ranged from a lowest of 68.15 ± 8.24 W/m2K to the highest of 458.37± 64.69 W/m2K. The highest and lowest U-values were obtained with T9 and T1 respectively. The U-value obtained in case of T8 was almost equal to the highest value, which was remarkable factor.

Overall heat transfer coefficients

The sensory characteristics of the noodles cooked in the self-heating container using the combinations T8 and T11 were evaluated using conventionally cooked noodles as control. From the results shown in Table 9, it is seen that all the scores of control for all the sensory attributes were significantly higher than the experimental products. Treatment T11 scored significantly higher than T8 and its flavour score was at par with that of control at 5 % level of significance. Although score is less it was acceptable.

Table 1: Proportion of dry noodles to cooking water

Quantity of dry noodles (gm)	**Quantity of cooking water (**ml)
40	40
	60
	80
	100
	120
60	60
	90
	120
	150
	180
80	80
	120
	160
	200
	240

Table 2: Treatment combinations for Design

Treatments	CaO (g)	H_2O (ml)
T1	**50**	**25**
T2	**50**	**50**
T3	**75**	**37**
T4	**75**	**75**
T5	**100**	**50**
T6	**100**	**75**
T7	**100**	**100**
T8	**125**	**75**
T9	**125**	**100**
T10	**125**	**125**
T11	**150**	**75**
T12	**150**	**100**
T13	**150**	**150**

Table 3 : Average Composition of the noodles	
Constituent	Mean Value % (Standard Deviation)
Carbohydrate	61.74 (0.908)
Protein	9.24 (0.776)
Fat	14.50 (0.704)
Ash	1.53 (0.147)
Water	12.88 (1.096)
n=5, Figures in parenthesis indicate standard deviation	

Table 4: Selection of Dry noodles to cooking water ratio.		
Weight of dry noodle (g)	Volume of Cooking water (ml)	Average sensory score for acceptability ± Standard Deviation
40	40	4.00 ± 0.632
	60	4.80 ± 0.748
	80	**7.80 ± 0.748**
	100	6.80 ± 0.400
	120	5.60 ± 0.800
60	60	3.20 ± 0.748
	90	4.60 ± 1.020
	120	**7.60 ± 0.800**
	150	6.80 ± 0.748
	180	4.20 ± 0.748
80	80	4.00 ± 1.095
	120	5.00 ± 0.632
	160	**7.60 ± 0.490**
	200	6.80 ± 0.400
	240	5.80 ± 0.748

Table 5: The values for analytical heat requirement (kJ) for cooking						
Weight of noodle, gm	Weight of Cooking water, gm	Specific Heat dry noodles, kJ	*Specific Heat of water, kJ/kg□C	Initial Temp,^{0}C	Final Temp, ^{0}C	Analytical Heat Reqd (kJ)
40	80	2.0608	4.1889	30	85	22.964
	100	2.0608	4.1889	30	85	27.646
60	120	2.0608	4.1889	30	85	34.447
	150	2.0608	4.1889	30	85	34.558
80	160	2.0608	4.1889	30	85	45.929
	200	2.0608	4.1889	30	85	46.077
Data represented as mean (n=5). *At average temperature of 57.7 □C.						

Table 6: The values for actual heat requirement (kJ) for cooking

Noodle (g)	Cooking Water (ml)	Water in reference, (g)	Initial Temp. (^oC)	Final Temp. (^oC)	Final weight, (g)	Water evaporated (g)	Actual Heat (kJ)	Actual Heat per gram (kJ/g)
40	80	120	30	95	111	9	52.99	0.442
40	100	140	30	97	124	16	75.40	0.539
60	120	180	30	95	165	15	82.87	0.460
60	150	210	30	96	186	24	112.23	0.534
80	160	240	30	94	221	19	107.22	0.447
80	200	280	30	97	232	48	186.92	0.668

Data represented as mean (n=3).

Table 7: Average rise in temperature in the product space over time

Treatments	1 min	2 min	3 min	4 min	5 min	6 min
T1	35.000 ± 0.00^k	37.666 ± 0.57^k	39.666 ± 0.57^i	41.000 ± 1.00^h	40.666 ± 0.57^g	39.666 ± 0.57^g
T2	33.333 ± 0.57^l	36.000 ± 1.00^k	38.000 ± 1.00^i	39.666 ± 1.15^h	40.333 ± 0.57^g	39.333 ± 0.57^g
T3	34.333 ± 1.15^{kl}	41.333 ± 1.15^j	44.666 ± 0.57^h	48.000 ± 1.00^g	50.666 ± 0.57^f	53.000 ± 1.00^f
T4	40.666 ± 0.57^j	48.333 ± 0.57^i	53.000 ± 1.00^g	59.333 ± 1.15^f	61.666 ± 0.57^e	63.666 ± 0.57^e
T5	43.666 ± 0.57^i	52.666 ± 0.57^h	57.333 ± 0.57^f	60.000 ± 1.00^f	62.000 ± 1.00^e	65.666 ± 0.57^d
T6	55.333 ± 1.52^h	64.333 ± 2.08^g	70.000 ± 1.00^e	74.333 ± 0.57^d	77.333 ± 0.57^b	80.000 ± 1.00^a
T7	59.000 ± 1.00^g	66.333 ± 1.15^f	72.333 ± 0.08^d	77.333 ± 1.15^c	76.333 ± 1.15^b	75.333 ± 0.57^b
T8	81.000 ± 1.00^b	87.666 ± 0.57^b	88.333 ± 0.57^a	82.666 ± 0.57^b	76.666 ± 1.52^b	74.333 ± 1.15^b
T9	71.333 ± 1.15^e	81.666 ± 0.57^d	87.000 ± 1.00^a	81.000 ± 2.64^b	76.333 ± 1.15^b	74.000 ± 1.00^b
T10	69.666 ± 0.57^f	79.333 ± 0.57^e	77.33 ± 1.52^c	74.666 ± 0.57^d	72.666 ± 0.57^c	70.333 ± 0.57^c
T11	86.666 ± 0.57^a	91.000 ± 1.00^a	88.666 ± 1.15^a	87.000 ± 1.73^a	81.333 ± 1.15^a	80.000 ± 1.00^a
T12	79.333 ± 1.15^c	84.666 ± 1.52^c	83.666 ± 1.15^b	77.666 ± 1.15^c	73.333 ± 1.52^c	70.333 ± 1.52^c
T13	74.333 ± 1.15^d	80.000 ± 1.00^{de}	76.666 ± 1.52^c	72.000 ± 1.00^e	69.333 ± 1.15^d	65.000 ± 1.00^{de}

Data represented as Mean ± Standard Deviation
Each observation is Mean of three replications (n=3)
Means bearing similar superscript within the column do not differ significantly ($p < 0.05$)

Table 8: Heat generation, transfer and recovery

Treatments	Theoretical heat of reaction, kJ	Heat received in the product space, kJ	Heat Recovery,%
T1	57.85	6.77 ± 1.23	11.70 ± 2.12
T2	57.85	6.52 ± 1.28	11.27 ± 2.21
T3	86.78	15.30 ± 1.28	17.63 ± 1.47
T4	86.78	22.57 ± 0.61	26.01 ± 0.71
T5	144.64	22.57 ± 1.23	19.51 ± 1.06
T6	144.64	35.86 ± 1.28	30.99 ± 1.11
T7	144.64	35.61 ± 1.55	30.78 ± 1.34
T8	115.71	45.14 ± 1.23	31.21 ± 0.85
T9	115.71	39.88 ± 1.63	27.57 ± 1.12
T10	115.71	35.61 ± 1.42	24.62 ± 0.98
T11	173.57	44.14 ± 1.28	25.43 ± 0.74
T12	173.57	39.12 ± 1.63	22.54 ± 0.94
T13	173.57	37.37 ± 0.94	21.53 ± 0.5

The figures indicated are the Means ± Standard deviation, (n=3)

Table 9: Sensory evaluation of noodles cooked in self-heating container.

Sensory attributes	T0 (Control)	T8	T11
Color	7.75 ± 0.45 ^{a}	4.58 ± 0.51^{c}	6.66 ± 0.65 ^{b}
Flavor	7.66 ± 0.49^{a}	4.58 ± 0.51^{b}	7.41 ± 0.66^{a}
Body and texture	7.83 ±0.38^{a}	4.25 ± 0.45^{c}	7.00 ± 0.85^{b}
Appearance	7.73 ± 0.38^{a}	4.41 ± 0.51^{c}	7.16 ± 0.57^{b}
Overall acceptability	7.91 ± 0.28^{a}	4.16 ± 0.38^{c}	6.91 ± 0.51^{b}

Data represented as mean ± standard deviation means with different superscripts in a column differ significantly at 5% level of significance (n=3)

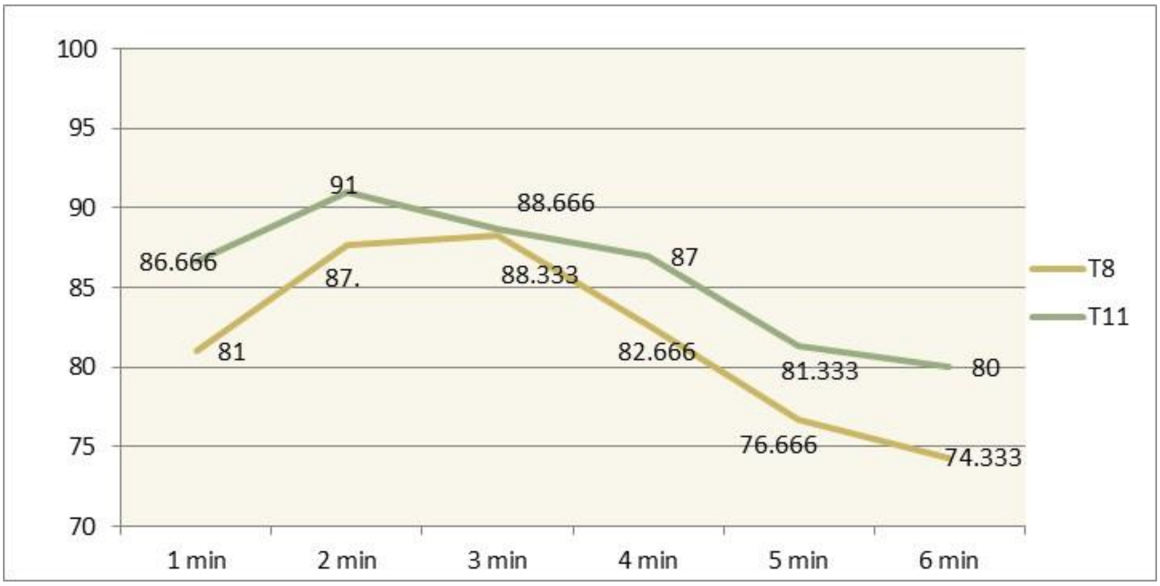

Fig. 1: Comparision of the combination of reactant T8 (125:75) and T11 (150:75)

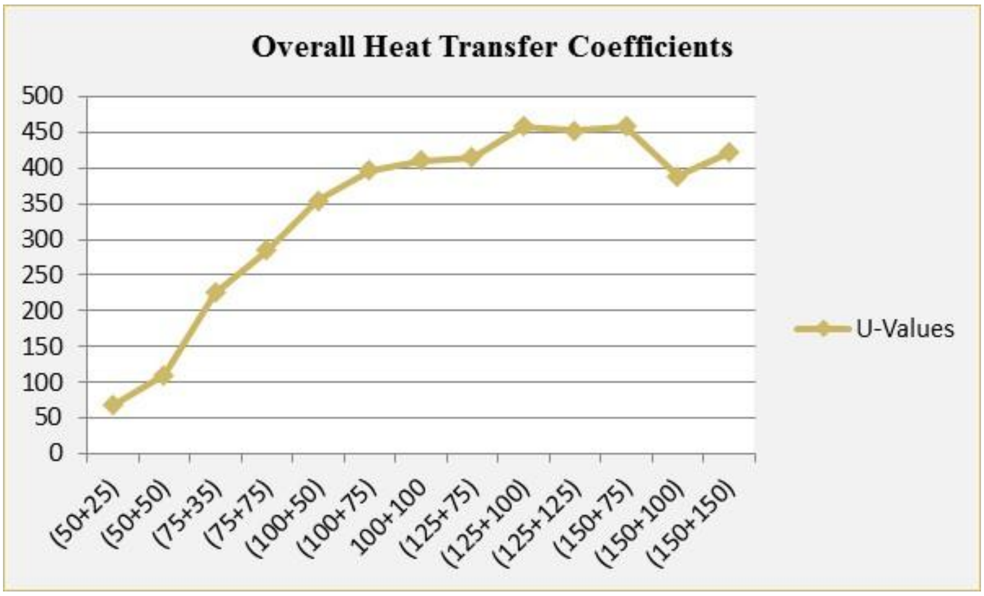

Fig. 2: Overall Heat Transfer Coefficients, W/m^{2}K

CONCLUSION

From the study it can be concluded that the mixture of 150 g CaO + 75 g Water is most suitable to heat up 60 g of noodles with 120 ml water within 2 minutes, in absence of any agitation. Both the reactants as well as bye products of the reaction are inexpensive, readily available and possess GRAS status. Hence, the food safety is also ensured.

FUTURE SCOPE & LIMITATIONS

Insulation to the container can improve heat recovery and thereby reduce the weight of the container. Light weight material can be tried to reduce the weight of the package. The cost of the container comes approximately 10 times that of the product, which needs to be reduced for commercial viability (mass production). The weight of the package is more than double that of the conventional package.

Acknowledgement

The authors are thankful to the College of Dairy Technology, Warud, Pusad for providing necessary fund and facilities to conduct the study.

REFERENCES

1. Choi Y. and Okos, M.R. (1983). Thermal Properties of Liquid Foods-Review. Winter Meeting American Society of Agricultural Engineers. Paper No. 83-6516, Chicago, IL.
2. https://www.techsciresearch.com/report/india-ready-to-eat-food-market-forecast-and-opportunities-2019/367.html
3. https://www.fda.gov/Food/IngredientsPackagingLabeling/GRAS/SCOGS/ucm260885.html