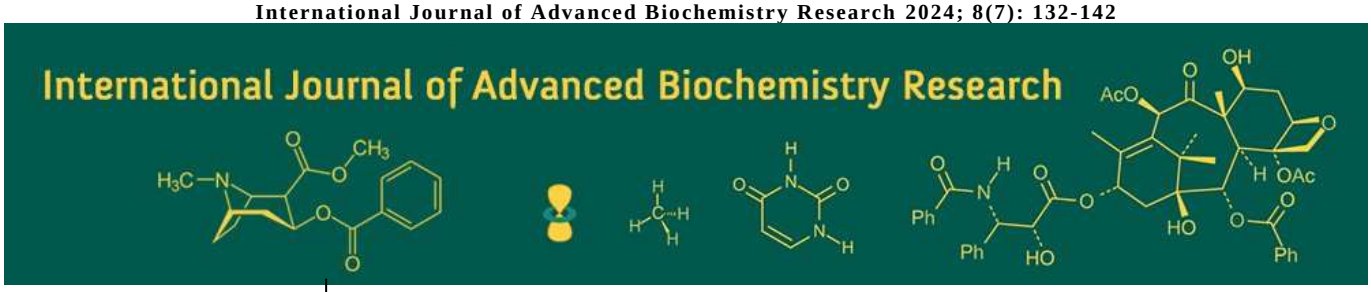

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Utilization of cheddar cheese into mozzarella cheese towards a better pizza experience as evident from textural, sensory and consumer research parameters

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Abstract
Mozzarella cheese is desirable on pizza for its unique textural proeprties, however, it lacks flavor since it is an unripened form of cheese. Therefore, in the present study cheddar cheese was blended with mozzarella cheese to have improved flavor acceptability. The acceptance of the developed blend of cheddar with mozzarella cheese was confirmed using consumer research based on central location test. JAR (Just about right) scores for Mozzarella-Cheddar Blend (70:30) was found to have parity performance in comparison with 100% Mozzarella in Margherita pizza. While in farmhouse pizza, Mozzarella Blend (70:30) was significantly rated above 100% Mozzarella in terms of Stretchability in Delhi, it was significantly rated above 100% Mozzarella in terms of Spreadability of cheese in Farmhouse pizza at Bangalore region.

Keywords: Pizza cheese, cheddar cheese, cheese blend, mozzarella, stretchability

Introduction
Pizza cheese encompasses several varieties and types of cheeses and dairy products that are designed and manufactured for use specifically on pizza. These include processed and modified cheese such as mozzarella-like processed cheeses and mozzarella variants. The term can also refer to any type of cheese suitable for use on pizza. A number of cheeses are being used as pizza cheese i.e. natural Mozzarella, Cheddar, Provolone, Parmesan, Emmental, Romano, Ricotta, Mozzarella analogue, Processed and Modified cheeses as described by Ma *et al*. (2014) [9]. Mozzarella is a southern Italian soft un-ripened cheese. It has a smooth elastic structure without curd granules and has near white colour. It is soft, white, and un-ripened cheese, which is consume shortly after manufacturing. (El Owni *et al*., 2009) [1]. Being a soft un-ripened cheese, it has a bland flavour due to no or very less biochemical changes happened during manufacturing. However, to improve the over taste profile of mozzarella cheese, hard variety cheeses like Cheddar or Provolone can be blended (Gulzar *et al*., 2020) [3]. Cheddar cheese is a relatively hard variety of cheese that undergoes significant changes during ripening. The biochemical changes occurring during ripening of cheddar are grouped into primary events including glycolysis, lipolysis, and proteolysis followed by secondary biochemical changes such as metabolism of fatty acids and amino acids, which are important for the production of secondary metabolites, including a number of compounds necessary for flavor development in ripened cheese (Murtaza *et al*., 2014) [10]. Fresh Mozzarella cheese shows a fibrous structure and melting and stretching characteristics upon cooking and use on pizza but lacks pleasant flavor characteristics. Similarly, ripened cheese lacks desirable texture but has good flavor characteristics (Kindstedt and Fox, 1993) [7].

Keeping in view the need of consumers, this study was planned uisng cheese blends by mixing mozzarella cheese with young cheddar cheeses at various proportions. The objective of this study was to assess the effect of different proportions of cheeses (Mozzarella and Cheddar) on the acceptance of pizza by customers with reduced dosage.

Material and Methods

Moisture Content

Moisture content was estimated using FSSAI 01.039:2022 method. 3g each cheese samples were weighed and transferred to a pre-dried flat-bottom dish (with a cover) that contain pre-weighed 20g sand and a stirring rod. The dish was put in an oven at 102 ± 1 °C for about 4 h and allowed it to cool to 25 ± 3 °C in desiccator and weigh it. Moisture content was calculated from loss in weight.

$$\text{Moisture \%} = \frac{Weight\ of\ sample\ (before\ drying - after\ drying)}{Weight\ of\ Sample} \times 100$$

Total Solids%= 100- moisture content%

Fat Content

The Fat content was analyzed by FSSAI 01.041:2022, Gerber method (IS1224 (Part II): 1977, Reaffirmed 2016). 10 ml Gerber sulphuric acid, 3g each cheese samples, 1ml amyl alcohol and warm water (30- 40 °C) added to butyrometer tube till 5mm reading. The tubes were kept in centrifuge for 5 min at 1100 rpm. Separated fat and acid scale reading was taken.

$$\text{Fat \%} = \frac{Fat\ (\%)}{Total\ Solids\ (\%)} \times 100$$

Protein Content

Protein content was analyzed by FSSAI 01.036:2022, Kjeldahl method. 5g of each cheese sample was transferred to 500mL Kjeldahl tubes. The tubes were heated in digestion apparatus for 1.8h till the digestion cleared. The distillation apparatus turned to release the condensed water. The distillate was then titrated with n/10 hydrochloric acid to determine the ammonia in boric acid.

$$\text{Nitrogen \%} = \frac{1.4007 \times (Vol.of\ HCl - Vol.of\ HCl\ in\ lank) \times Normality\ of\ HCl}{Weight\ of\ Sample}$$

Protein% = Nitrogen (%) × 6.25

Ash Content

The ash content was estimated by FSSAI 01.064:2022 method. Pre-dried and weighed 3g each cheese samples were taken crucibles and heated in a muffle furnace at 550 ± 20 °C till grey ash is obtained. The crucibles were cooled in desiccator and weighed.

$$\text{Ash \%} = \frac{Weight\ of\ crucible\ and\ ash - weight\ of\ empty\ crucible}{Weight\ of\ moisture\ free\ Sample} \times 100$$

Titratable Acidity

The acidity of cheese samples was estimated by FSSAI 01.035:2022, titration method. 10g each cheese samples were added to 30ml warm water and 1ml phenolphthalein indicator in a flask titrated against 0.1N NaOH solution till the colour matched to control sample. The acidity calculated as per the formula

$$\text{Titratable Acidity \%} = \frac{9 \times Vol.of\ NaOH\ for\ titration \times Normality\ of\ NaOH}{Weight\ of\ Sample\ taken} \times 100$$

Salt

The salt content was estimated using IS: 2785.1979, Nitrate solution method. 2g each cheese samples were taken and 25ml of 0.05N standard silver nitrate solution titrated with 0.05N potassium thiocyanate solution till the orange tint appeared. The salt content was calculated using the formula

$$\text{Salt \%} = \frac{0.292\ (Vol.\ of\ Potassium\ thiocyanate - Vol.\ of\ thiocynate\ after\ titration)}{Weight\ of\ Sample\ taken} \times 100$$

Consumer research (CLT)

Basis the evaluation from trained sensory panelist, mozzarella and cheddar (70:30) at 10% less dosage than of existing was taken ahead for conducting consumer research in Delhi and Bangalore region (Overall n=303, Delhi n=154, Bangalore n=149) following the steps shown in Fig. 1. Face to face interviews conducted at Central location test (CLT) venues using CAPI methodology (Computer-Assisted Personal Interviews (CAPI). Equal Male to Female ratio was taken between age 18-24 and 25-40 years. Panelist were equally divided between food. Sequential Monadic design was used where each consumer tasted 2 products of same type.

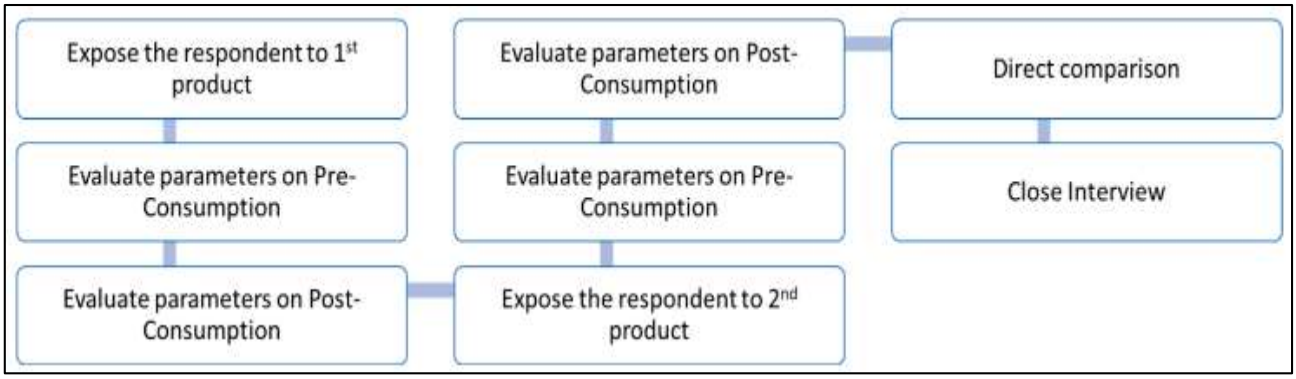


Fig 1: Steps followed for consumer research

Manufacturing process

The manufacturing process for the mozzarella cheese and cheddar cheese (ripened for 3 to 4 months only) is shown in Fig. 2 and Fig. 3, respectively. The blend of the two was developed (Fig. 4) for preparing the test samples.

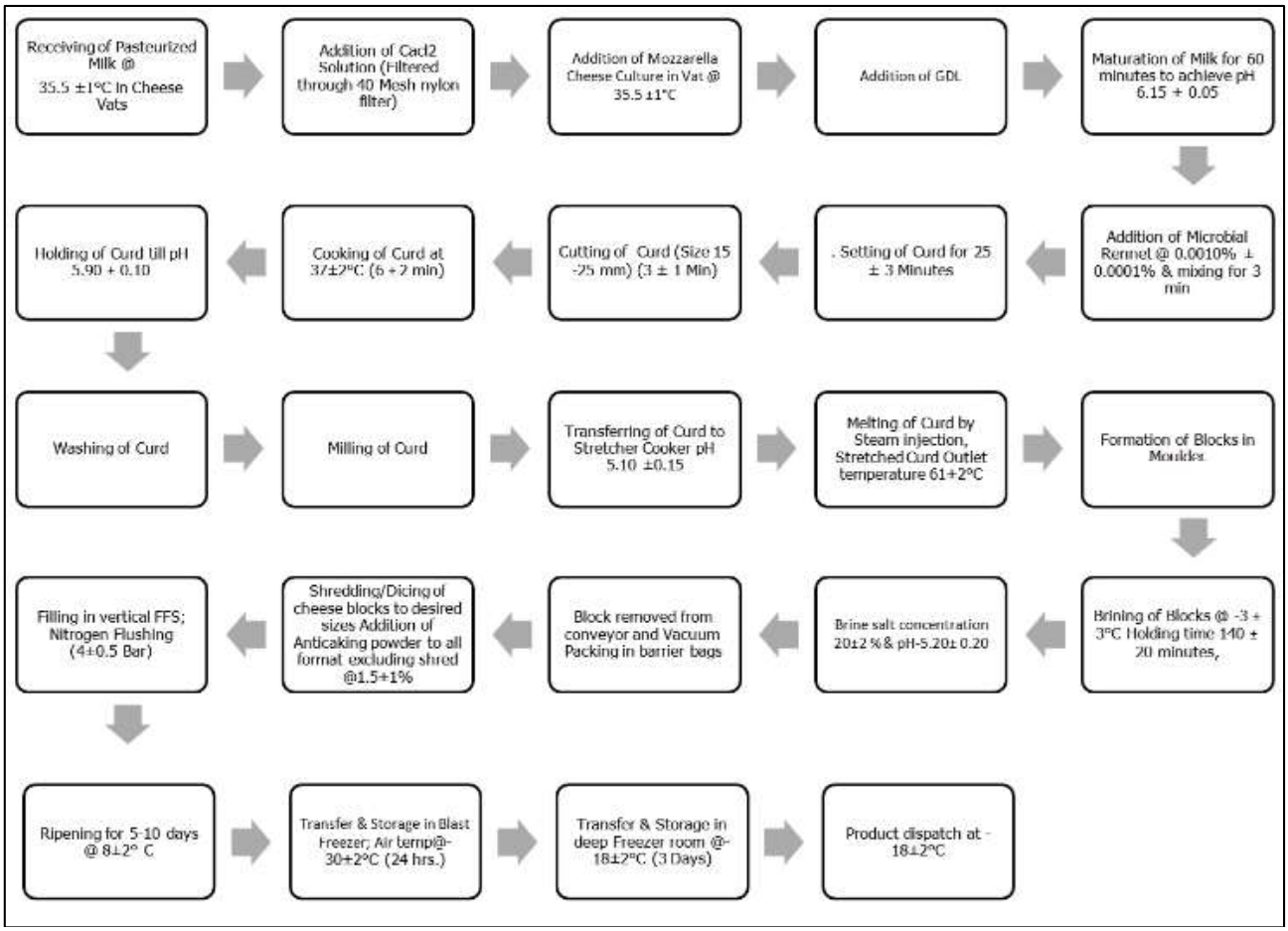


Fig 2: Mozzarella cheese

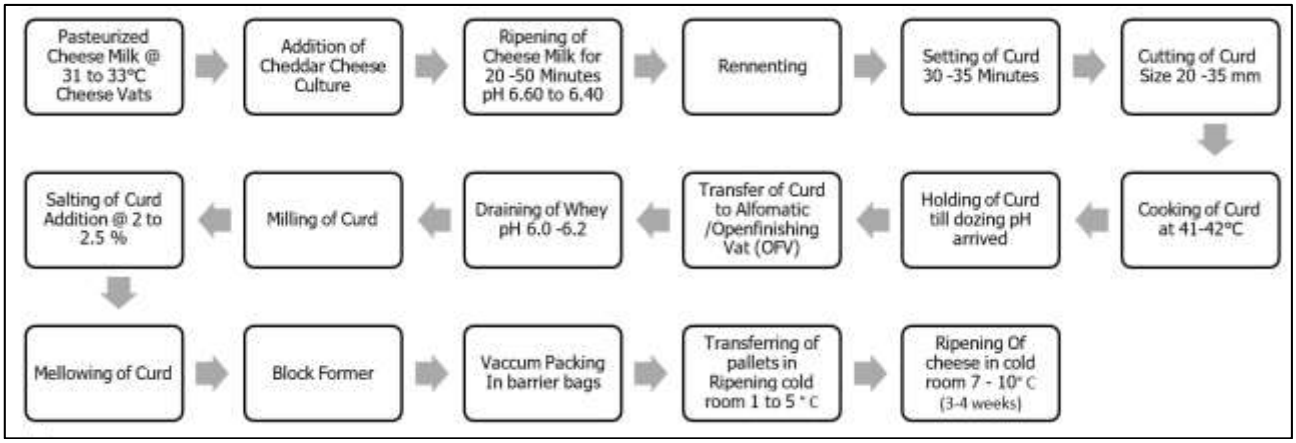


Fig 3: Cheddar cheese (Young)

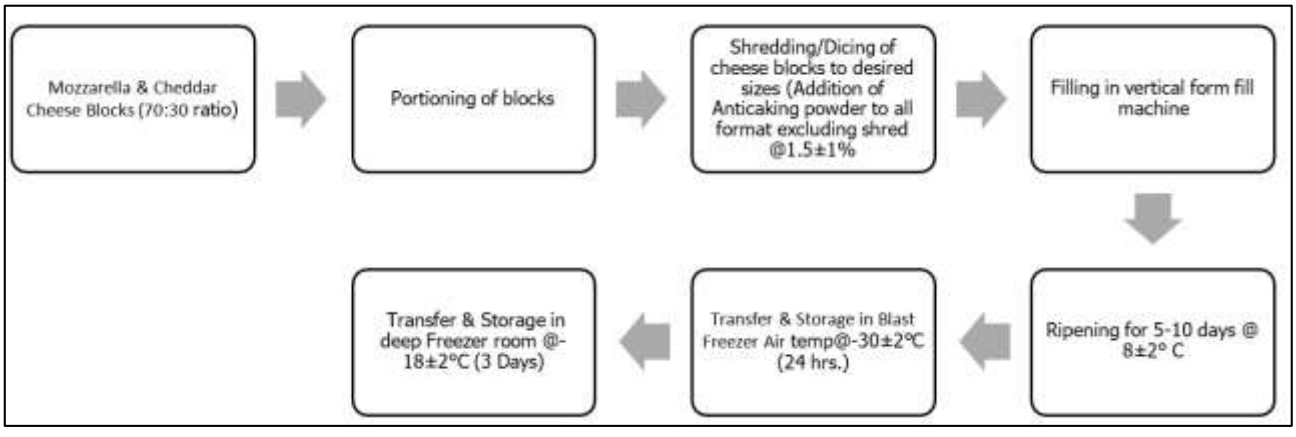


Fig 4: Mozzarella- cheddar blend

Results and Discussion

Trained panel sensory for screening of samples

Blend of Mozzarella and cheddar (70:30 and 80:20) at 10% less dosage than of existing (95g per medium pizza) were evaluated against the 100% Mozzarella cheese by 24 trained sensory panelists (Plate 1). Margherita pizza was chosen for application testing, being having only pizza sauce and cheese as ingredient to give clear picture of research to be done. Samples were coded with 3 digit randomized monadic presentation. Sample data was collected and evaluated using Compusense ® Software. Pizza with Mozzarella and cheddar (70:30) at 90% dosage was preferred more on overall likeability, aroma and flavor. It was found to have good overall flavor release, cheesy and soft texture.

Basis the above evaluation from trained sensory panelist, Mozzarella and cheddar (70:30) at 10% less dosage than of existing was taken ahead for conducting consumer research in Delhi and Bangalore region (Overall n=303, Delhi n=154, Bangalore n=149).

Plate 1: Two types of Pizza (Margherita and Farm House) with 100% Mozzarella cheese and the blend (70:30).

Chemical analysis

The chemical analysis data of Mozzarella, Cheddar and 70:30 mix is shown in the

Table 1. Chemical analysis of Mozzarella, Cheddar and 70:30 mix

Parameters	Control Mozz (A)	Cheddar (B)	70:30 blend (C)
Moisture%	48.81	37	47.12
Protein%	21	28.54	22.27
Fat%	21.25	28.16	23.54
Salt%	1.35	1.74	1.49
Melting point (°C)	55	66	58

Moisture content

Addition of Hard variety of cheese (Cheddar) in the blend lowers down the moisture content. Sample A (Mozzarella) was found to have highest moisture of 48.81%, while Sample B (Cheddar) and Sample C (70:30 blend) were found to have 37% and 47.12%, respectively.

Fat content

Sample C (70:30 blend) was found to have 23.54% fat against 21.25% in Sample A (Mozzarella). Increase in fat also improves the richness and taste of product, which is evident from consumer research results also.

Salt content

Sample C (70:30 blend) was found to have 1.49% salt against 1.34% in Sample A (Mozzarella). Although it is under the spec range of Mozzarella cheese (1-1.8%). Blending of cheddar may be responsible for the slight increase in salt%.

Meltability

Meltability is one of the most important functional properties of cheese, especially in the application of cheese in pizza. Cheese with poor meltability is tough and hardly stretchable, while excessive melting may result in a "soupy" appearance of cheese. Both of these are considered unacceptable for products like pizza (Wang and Sun, 2002) [11]. After baking of Margherita pizza, meltability was checked qualitatively. Absence of any intact dice or semi-melted dice is the not desired. Pizza made from Mozzarella blend (70:30) was found to have melting at par with the 100% Mozzarella (Plate 2). A cheese with more moisture will also have more loosely packed milk proteins, which separate more easily when heated. That's why a harder, drier cheese like Parmesan becomes oily and greasy instead of creamy, as compared to a moister. Younger cheeses tend to melt more easily than older ones. Sample A (Mozzarella; 55 °C) was found to have lower melting point than Sample C (70:30 blend; 58 °C) due to presence of more moisture. Sample B (Cheddar) was found to have melting point of 66 °C which is comparably higher than Sample A and C. Though on Pizza, no difference was observed in melting properties.

Plate 2: Meltability of Mozzarella blend (70:30)

Stretchability

Mozzarella cheese owes its rheological characteristics mainly to the action of acid on dicalcium-para- caseinate. Acidification of the milk leads to higher solubilisation of colloidal calcium and a lower level of protein-associated calcium in the mozzarella cheese (Guinee *et al.*, 2002) [2], which enables stretching to occur (Lucey, J. A et al., 2003) [8]. Therefore, the lower fraction of insoluble calcium increases the hydration of casein, resulting in an increase in moisture and melting of mozzarella cheese. During the kneading of curd, it develops the elastic properties that makes it suitable for use in Pizza (Jana *et al*., 2011) [4].

Plasticization and stretching are governed by the casein-associated calcium content at the time of stretching, which in turn is modulated by the total calcium content and the curd pH. Stretching is a thermomechanical treatment involving the application of mechanical energy (in the form of shear stress) and temperature. There are two essential parameters that need to be controlled for optimal curd stretching. The first is that the curd needs to be sufficiently acidified and demineralized, and the second parameter is the heat transfer between the curd and the water or the brine during stretching (Kindstedt, 2007) [6].

Addition of young cheddar cheese (aging less than 4 weeks) is expected not to impact much on stretching properties of mozzarella. As the aging and proportion of blending of cheddar increase, it is expected to reduce the stretch properties. During stretch analysis of Mozzarella blend on Margherita pizza, it was found to have stretch of 17cm with product core temperature of 76 °C (Plate 3).

Plate 3: Stretch test of Mozzarella blend (70:30)

Colour evaluation

Cheddar cheese is characterized by pale yellow colour. Mozzarella is a southern Italian soft un-ripened cheese. It has a smooth elastic structure without curd granules and has near white colour. It is soft, white, and un-ripened cheese, which is consume shortly after manufacturing. (El Owni *et al.*, 2009) [1]. Cheddar cheese is a relatively hard variety of cheese that undergoes significant changes during ripening. During baking, formation of a gel increases light scattering, which increases L*value. While during cooling, the gel dissociates and no longer scatters light, which decreases L*-value.

Table 2: Colour Values for the Mozzarella, Cheddar and 70:30 mix

Product	L*	a*	b*
Cheddar	86.12±1.97	4.75±0.75	31.71±1.99
Mozzarella	89.07±1.53	2.43±0.50	23.23 ±1.50
70:30 mix	88.02±0.97	3.61±0.42	27.16±1.13

	Range	
L*	0	100
a*	-60	60
b*	-40	80

Comparison of L* values

Comparison of lightness using Hunter color meter was done. Cheddar cheese was found to be significantly darker in comparison with Mozzarella and 70:30 mix (Table 2). A student's t-test was used to analyse the level of significance between Mozzarella, cheddar and 70:30 mix. All three were found to be significantly different in L* values in order of Mozzarella (89.07±1.53), 70:30 mix (88.02±0.97) and Cheddar cheese (86.12±1.97). The higher level of whiteness in Mozzarella is due to higher level of moisture content and heterogeneous structure of Mozzarella which provides greater surface area for scattering of light (Pastorino et al., 2002). The reduction in the strength of whiteness with advancement in maturing months of cheese is linked with decreased level of intact casein and bound calcium. The bound casein and calcium in the cheese are the main components that gives white color to cheese (Joshi *et al*., 2003).

H0: There is no significant difference between the mean L* values of Mozzarella and Cheddar.

H1: There is a significant difference between the mean L* values of Mozzarella and Cheddar (p<0.05) (Table 3).

Table 3: Student's t-test values for L* values

	Mozzarella	Blend	Cheddar	Blend	Cheddar	Mozzarella
Mean	89.07	88.02	86.12	88.02	86.12	89.07
Variance	2.33	0.94	3.89	0.94	3.89	2.33
Observations	49	49	193	49	193	49
Hypothesized Mean Difference	0		0		0	
df	81		158		93	
t Stat	4.033		-9.582		-11.311	
P(T<=t) one-tail	6.19E-05		9.91E-18		1.80E-19	
t Critical one-tail	1.664		1.655		1.661	
P(T<=t) two-tail	1.24E-04		1.98E-17		3.60E-19	
t Critical two-tail	1.990		1.975		1.986	

Comparison of b* values

The biochemical changes occurring during ripening of cheddar are grouped into primary events including glycolysis, lipolysis, and proteolysis followed by secondary biochemical changes such as metabolism of fatty acids and amino acids, which are important for the production of secondary metabolites, including a number of compounds necessary for flavour development in ripened cheese (Murtaza *et al*., 2014) [10]. ±b* represent the degree of yellowness to blueness on a scale from blue (-) to yellow (+). Different blends of Mozzarella and cheddar were evaluated, where it was found that the whiteness decrease significantly (Table 4) with increasing level of Cheddar cheese in Pizza cheese blends. An increase in redness and yellowness with increasing level of Cheddar cheese in Pizza cheese blends has also been previously reported in the literature (Murtaza *et al*., 2014) [10].

Table 4: Student's t-test values for b* values

	Mozzarella	Blend	Cheddar	Blend	Cheddar	Mozzarella
Mean	23.23	27.16	31.71	27.16	31.71	23.23
Variance	2.24	1.37	3.97	1.37	3.97	2.24
Observations	49	47	193	47	193	49
Hypothesized Mean Difference	0		0		0	
df	90		120		96	
t Stat	-14.353		20.423		32.930	
P(T<=t) one-tail	2.70E-25		3.65E-41		2.08E-54	
t Critical one-tail	1.662		1.658		1.661	
P(T<=t) two-tail	5.41E-25		7.31E-41		4.16E-54	
t Critical two-tail	1.987		1.980		1.985	

Comparison of a* values

The changes in a* value (green to red color) with the blending of Mozzarella and Cheddar cheese is due to difference of reaction substrates of both cheese. Cheddar cheese has more reaction substrates due to increased levels of proteolysis and lipolysis and is more susceptible to browning as compared to Mozzarella cheese (Metzger *et al*., 2000). As the proportion of Cheddar cheese and ripening

period increases in the pizza cheeses, negative a* value becomes less (more red colour) (Table 5). It is due to higher concentration of galactose that gives brown color due to its greater molar concentration and reactivity (Dattatreya *et al*., 2010 and Ma *et al*., 2014) [9].

Table 5: Student's t-test values for a* values

	Mozzarella	Blend	Cheddar	Blend	Cheddar	Mozzarella
Mean	2.43	3.61	4.75	3.61	4.75	2.43
Variance	0.25	0.17	0.56	0.17	0.56	0.25
Observations	49	47	193	47	193	49
Hypothesized Mean Difference	0		0		0	
df	92		127		109	
t Stat	-12.590		14.072		25.982	
P(T<=t) one-tail	5.04E-22		5.48E-28		8.14E-49	
t Critical one-tail	1.662		1.657		1.659	
P(T<=t) two-tail	1.01E-21		1.10E-27		1.63E-48	
t Critical two-tail	1.986		1.979		1.982	

Sensory evaluation

Flavor Descriptors of cheese

The sensory scores of flavor descriptors of Pizza cheeses are shown in Fig 5. It can be observed higher scores were obtained as the level of Cheddar cheese was increased in the Mozzarella- cheddar mix. The amalgamation of Mozzarella and ripened Cheddar cheeses is found to be a useful process to enhance the flavor characteristics of Pizza cheese. Biochemical changes that occur in ripened Cheddar are responsible for the enhanced flavor of Pizza cheese (Singh, *et al*., 2003) [12]. The lipolytic and oxidative changes in Cheddar cheese also contribute specific flavor and enhance sensory acceptability of Pizza cheese. For example, free fatty acids contribute to flavor precursors to cheese such as acids from C4:0 and C12:0, which impart specific flavors i.e., rancid, sharp, goaty, soapy, and coconut-like (Aston and Dulley, 1982) [14]. In Pizza cheese, the proportion of hydrolytic products of protein (peptides and amino acids) was increased with the level and age of Cheddar cheese that may also be responsible for the development of suitable cheese flavor. The acidic flavor in Pizza cheese is due to lactate that is generated in many reactions such as oxidation and microbial metabolism (McSweeney and Fox, 2004) [15].

The variation in taste was found to be least in 70:30 and 60:40 mix. This may be due to the higher levels of Cheddar cheese in the blend, giving pronounced cheesy taste note. As per regression equation, taste score is directly proportional to% Cheddar in Blend. More ripened Cheddar cheese imparts a rich flavor to the Pizza cheese, which is related to higher fat and protein contents, and glycolysis, lipolysis, and proteolysis processes occurring during maturation (Khattab *et al*., 2019) [13]. However, the highest Taste Score obtained was at 70:30 ratio (Fig. 6).

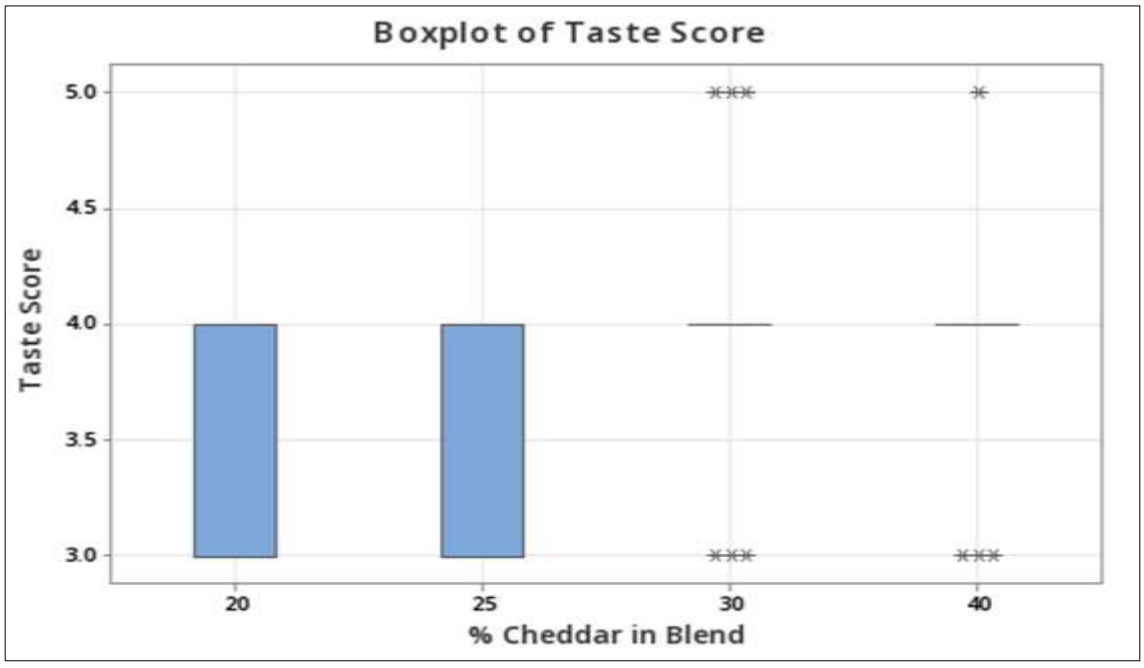


Fig 5: Boxplot of taste score vs. cheddar% in the blend

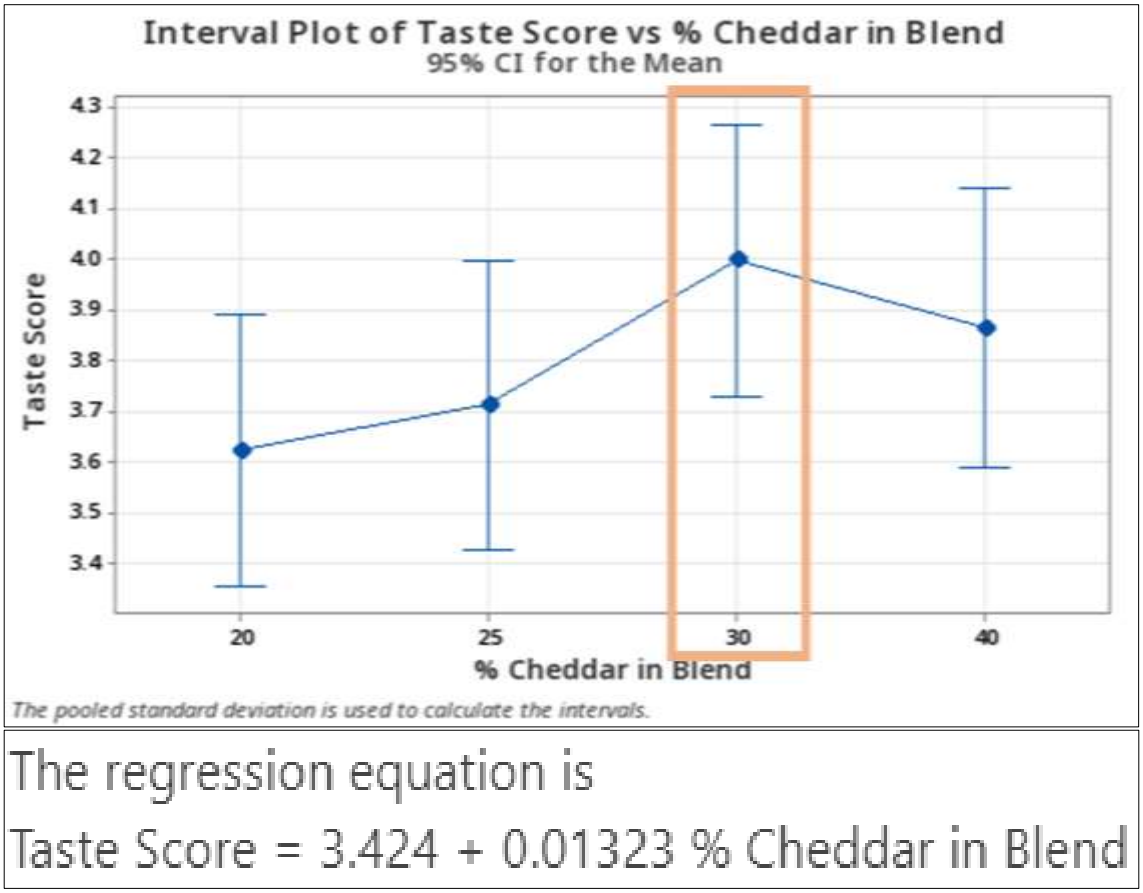
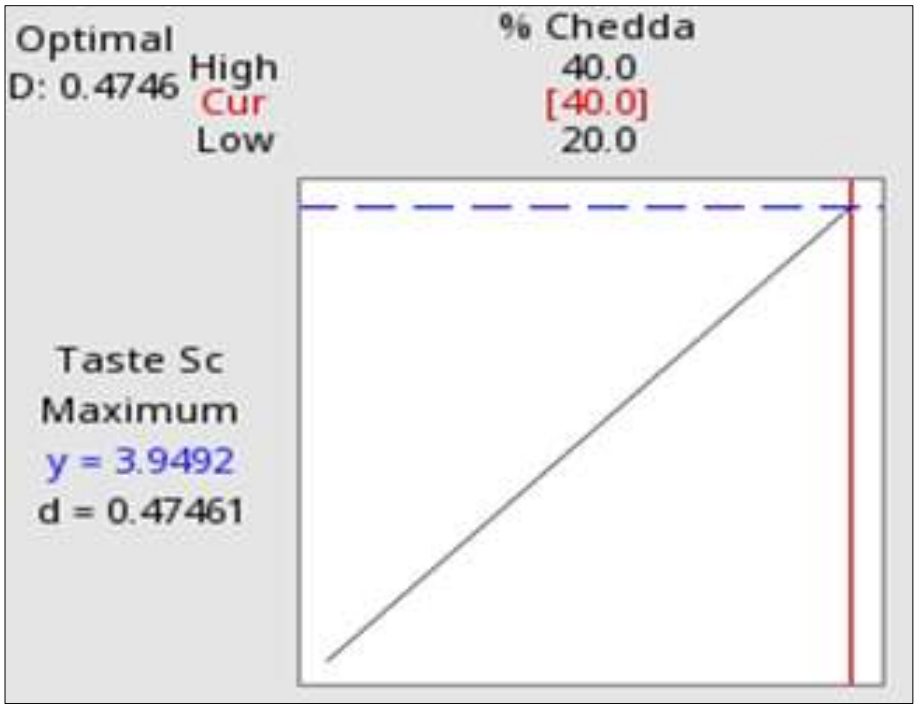


Fig 6: Taste Score vs. Cheddar% in the blend

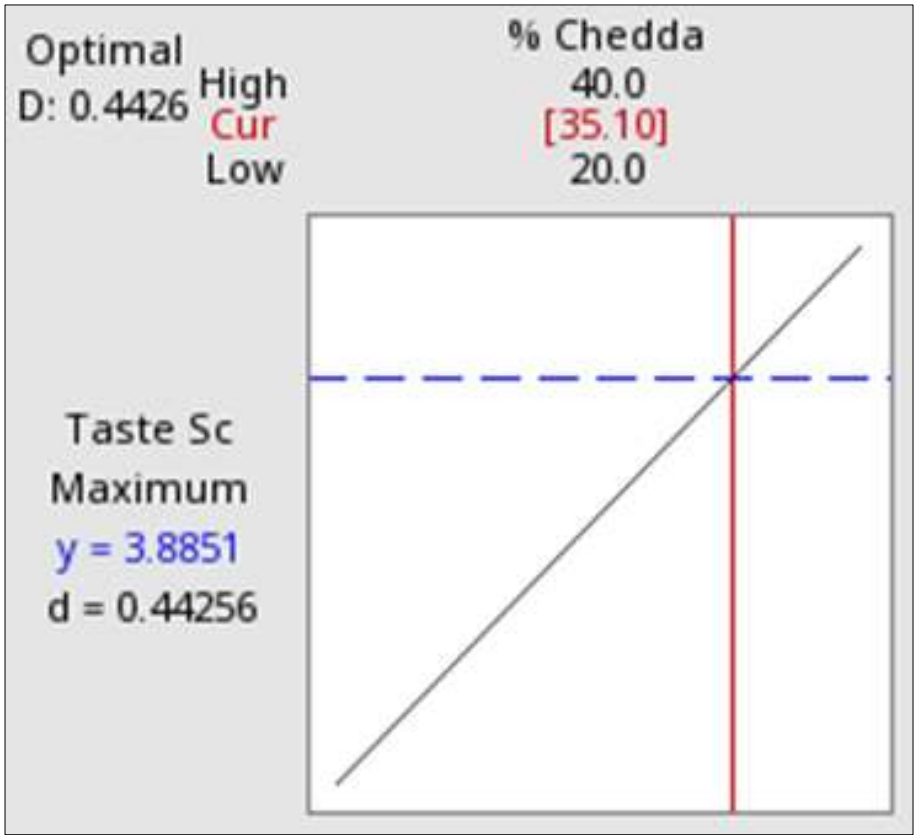
Multiple Response Prediction (60:40 Blend Ratio)

% Cheddar in Blend	Taste Score Fit
40	3.94921



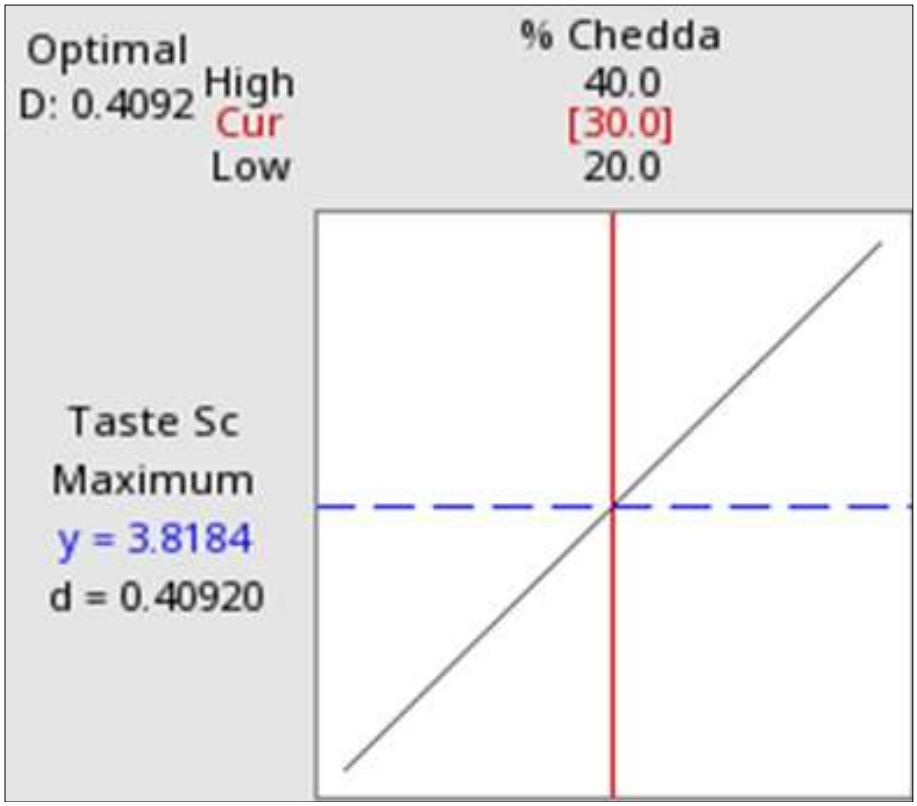
Multiple Response Prediction (65:35 Blend Ratio)

% Cheddar in Blend	Taste Score Fit
35	3.88380



Multiple Response Prediction (70:30 Blend Ratio)

% Cheddar in Blend	Taste Score Fit
30	3.81840



Multiple Response Prediction (75:25 Blend Ratio)

% Cheddar in Blend	Taste Score Fit
25	3.75299

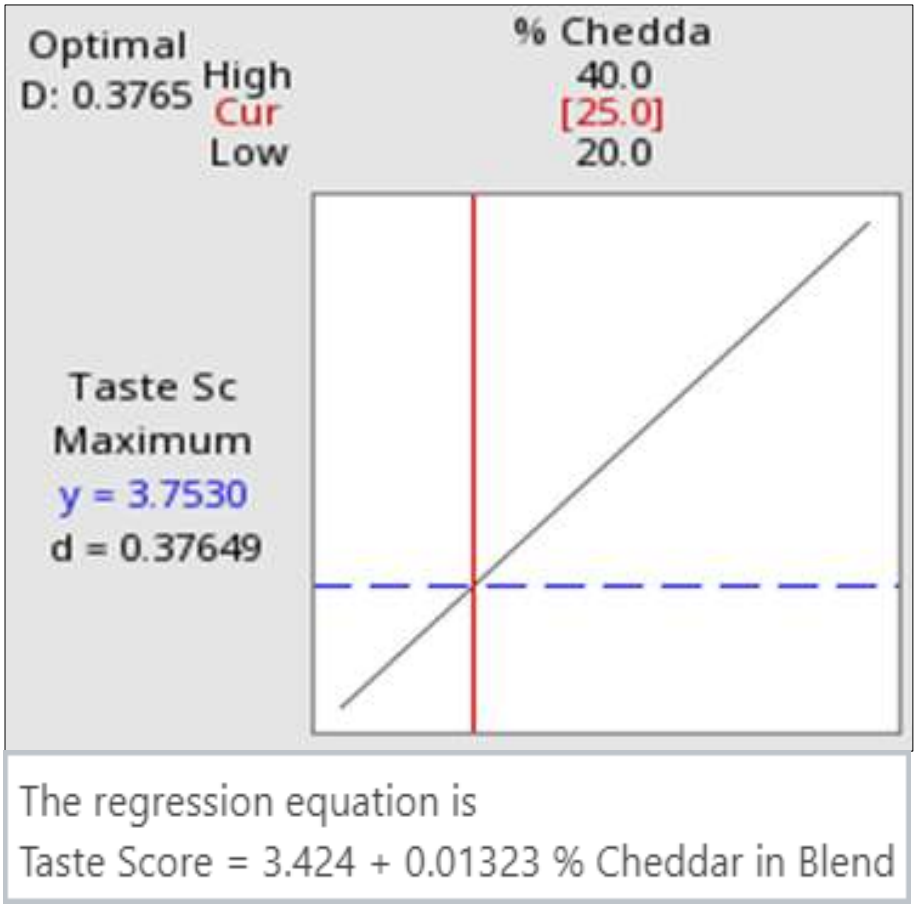


Fig 7a: Multiple response prediction for different blends of Mozzarella and cheddar cheese

Basis the regression equation (Fig. 7a) and the contour plot (Fig. 7b), it can be interpreted that the taste score and% of cheddar in the blend is positively related. As the value of the independent variable (% cheddar) increases, the mean of the dependent variable (Taste score) also tends to increase.

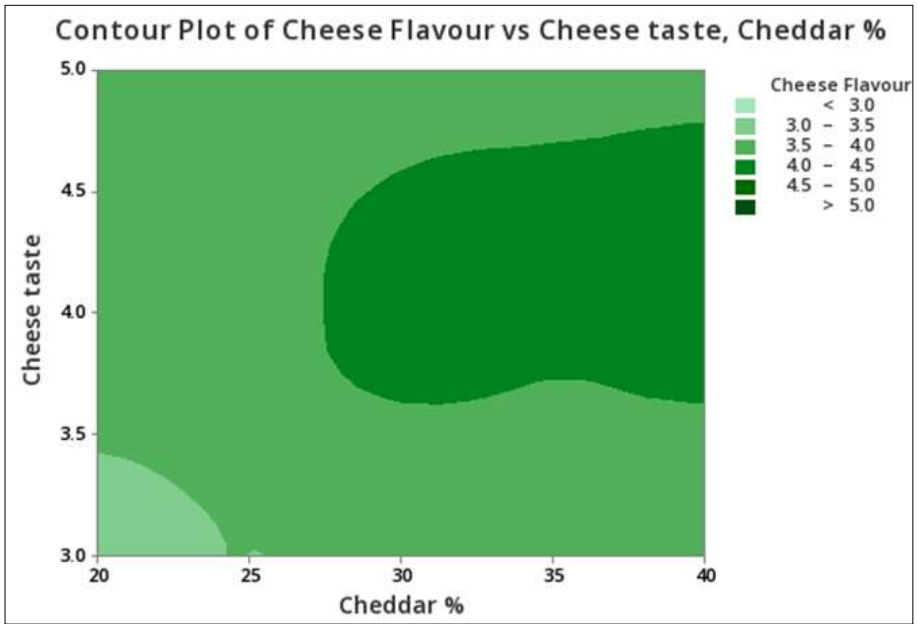


Fig 7b: Taste of cheese blend vs. cheddar cheese% in the blend

Consumer research (CLT)

Central location test (CLT) were conducted at Delhi and Bangalore. Mozzarella Blend (70:30) was found to be at par with 100% Mozzarella on all action standards (Overall likeability, Overall taste and Purchase intent) in both Margherita and farmhouse pizza at both the locations. In Margherita pizza, it was rated significantly better on Purchase Interest (Top 2 box – 96%), while in farmhouse pizza it was rated significantly better on Purchase Interest at an Overall level (Top 2 box – 91%) mainly driven by Bangalore (Top 2 box – 95%).

On color of pizza at pre-consumption stage, Mozzarella Blend (70:30) was rated significantly better (Top 3 box – 96%) in Margherita pizza at an overall level. Consumers in Bangalore rated the Mozzarella Blend (70:30) significantly better on Aroma of Cheese (Top 3 box – 92%) as compared to 100% Mozzarella in Margherita pizza and in Farmhouse pizza (Top 3 box – 97%) in Delhi.

On an overall level (post consumption), the Mozzarella Blend (70:30) was rated significantly better on Taste (Top 3 box – 93%), Spreadability (Top 3 box – 92%) and Mouthfeel (Top 3 box – 92%) on Margherita pizza. Domino's consumers rated it significantly better on Taste, Texture, Spreadability and Flavor of Cheese.

In Bangalore region, the Mozzarella Blend (70:30) rated significantly better on Taste and mouthfeel of Cheese as compared to 100% Mozzarella. Parity performance seen in Delhi. On an overall level (post consumption), the Mozzarella Blend (70:30) was rated significantly better on Quality of cheese (Top 3 box – 93%), Stretchability (Top 3 box-90%), Flavor (Top 3 box – 93%), and Mouthfeel (Top 3 box-93%) on Farmhouse pizza. Consumers rated it significantly better on quality of cheese, Spreadability, Stretchability, and Flavor and mouthfeel of Cheese.

JAR (Just about right) scores were taken to measure the appropriateness of the level of specific attributes *viz*. Greasiness, Quantity, Spreadability, Stretchability, Chewiness and dryness of cheese. Mozzarella Blend (70:30) was found to have parity performance on JAR score in comparison with 100% Mozzarella in Margherita pizza. While in farmhouse pizza, Mozzarella Blend (70:30) was significantly rated above 100% Mozzarella in terms of Stretchability in Delhi. In Bangalore region, Mozzarella Blend (70:30) was significantly rated above 100% Mozzarella in terms of Spreadability of cheese in Farmhouse pizza.

Overall, Mozzarella Blend (70:30) was significantly liked on cheese flavor in both Delhi and Bangalore region.

Conclusion

The Mozzarella Blend (70:30) was significantly preferred versus 100% Mozzarella and can be used as replacement of Mozzarella in Pizza. It will also result in significant amount of cost in use due to reduction in dosage. Though a significant difference (p<0.05) has been found in the L*, a* and b* values of Mozzarella, cheddar and 70:30 mix, Mozzarella Blend (70:30) was found to have parity performance on JAR score in comparison with 100% Mozzarella in Margherita pizza.

Conflicts of interest: None

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