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Cost assessment of mozzarella cheese analogues prepared using different types of casein

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Abstract
Three types of Mozzarella cheese analogues (MCAs) had been prepared using acid casein (AC), rennet casein (RC) and blend of them and cost of the analogues were compared with natural Mozzarella cheese (NMC) of reputed brand available in the market. Acid casein based MCA (ACMCA) was cheapest among all owing to lower cost of acid casein than rennet casein; similarly rennet casein based MCA (RCMCA) was costliest among all due to higher cost of rennet casein while the cost of MCA prepared using blend of RC and AC (ARCMCA) was in between. The raw materials cost was 82.87, 83.98 and 83.37 per cent of the total product cost for ACMCA, RCMCA and ARCMCA respectively. The total costing was Rs. 178.60, Rs. 191.00 and Rs. 184.00 for ACMCA, RCMCA and ARCMCA respectively for products prepared in the present study. The cost of ACMCA, RCMCA and ARCMCA was 38.42, 34.14 and 36.56 per cent cheaper respectively as compared to NMC.

Keywords: Mozzarella cheese, Mozzarella cheese analogues (MCAs), Acid casein (AC), Rennet casein, Cost

1. Introduction
Cheese is a fermented milk product, produced in a great range of flavours, textures and forms available throughout the world. Cheese has become a food of *haute cuisine* with epicurean qualities as well as a highly nutritious food. There are more than 1000 varieties of cheeses (Fox, 1993) [10]. Among these, *Pasta-filata* is a unique family of cheeses, which includes cheeses like Provolone, Caciocavallo, Mozzarella, etc., distinguished by plasticizing and kneading treatment of the fresh curd in hot water, imparting characteristics fibrous structure as well as melting and stretching properties to the product. Some of the principal Italian cheese varieties, especially Parmesan, Romano and Mozzarella have gained status of international recognition. Other factors contributing to the spread of Italian cheeses are the increasing popularity of Italian dishes, such as pizza which has created demand for Mozzarella cheese (Battistotti and Corradini, 1993; Jana and Tagalpallewar, 2017) [5, 15].

Cheese analogue is a substitute for milk based cheese, which is similar in composition, appearance, characteristics and even in its intended use to that of natural cheese. In cheese analogues, the milk fat and in some cases even milk proteins are partly or wholly replaced by vegetable fats and oils (viz. palm, rapeseed, partly hydrogenated vegetable fat from soybean, corn, etc.) and vegetable proteins (viz. soybean protein, peanut protein, etc.) respectively (Ahmed *et al.*, 1995; Hennelly *et al.*, 2005; Noronha *et al.*, 2008a; Cunha *et al.*, 2010; Arimi *et al.*, 2012) [1, 13, 22, 8, 2]. According to Codex Alimentarius Commission (1995) [7] cheese analogues are products which look like cheese, but in which the milk fat has been partly or completely replaced by other fats. Cheese analogues are formulated and produced with desired nutritional, functional and storage properties as per the market and consumer needs. Cheese substitutes are fabricated in a manner similar to that for processed cheese and the product finds application in baking, as a topping on pizza pie (Chavan and Jana, 2007) [6].

The cheese substitutes are categorized into two types, viz. (a) Filled cheeses, and (b) Cheese analogues. Filled cheeses are matured products made using vegetable oils/fats and prepared by conventional cheese manufacturing methods, while cheese analogues are non-matured products involving processed cheese manufacturing method (Badem and Ucar, 2016) [4]. The analogue cheeses are further classified into three types, namely (a) Dairy analogue, (b) Partial dairy analogue, and (c) Non-dairy analogue, depending upon the type of protein and fat sources used in their preparation (Bachmann, 2001) [3].

The estimated global cheese market was worth US $ 72.45 billion in 2012 (Jayadevan, 2013) [17]. The Indian organized cheese market, including its variants like processed cheese, mozzarella cheese, cheese spreads, flavoured and spiced cheese is valued at Rs. 4.5 billion. The annual market of processed cheese in India is worth Rs. 2.7 billion (Jana, 2015) [14]. In India, Amul holds 60.0 per cent of the total cheese market, while Britannia Milkman holds 25.0 per cent volume. Le Bon, Go Cheese and other regional brands such as Mother Dairy and Vijaya holds a share of 10.0 per cent and remaining 5.0 per cent has been captured by imported brands like Kraft, Laughing Cow, etc. (Sabikhi *et al.*, 2015) [24].

These days, the use of cheese and cheese spreads has increased in the urban mainstream. Cheese is bought in the form of cheese blocks, grated cheese and cheese spreads. Mozzarella cheese is now easily available in Indian market. The high demand of Mozzarella cheese stems from its emergence as an integral part of pizzas. Even though this cheese is often substituted with other cheeses while making pizza, nothing can make a pizza look, feel and taste like pizza, as does Mozzarella. India is the third largest market for Dominos' Pizza, after the US and the UK, but household cheese penetration is just 5.0 per cent, with 50.0 per cent of consumption in the urban areas (Jayadevan, 2013) [17].

The production of Mozzarella cheese as a specialty cheese is picking up in India since 2000, especially due to the emergence of successful business enterprise – the pizza parlour (Muslow *et al.*, 2007) [20]. Cheese analogues are being sold in UK, Japan, Sweden, France, Germany, Belgium, etc. Mozzarella cheese analogue (MCA) is widely distributed in the USA and is gradually winning a share of the European market (O' Riordan *et al.*, 2011) [23].

According to USDA (2007) [30] Mozzarella cheese is classified into four variants viz. Mozzarella cheese (52.0-60.0 per cent moisture, minimum 45.0 per cent FDM); low-moisture Mozzarella cheese (45.0-52.0 per cent moisture, minimum 45.0 per cent FDM); part-skim Mozzarella cheese (52.0-60.0 per cent moisture, 30.0-45.0 per cent FDM) and low-moisture part skim Mozzarella (LMPSM) cheese (45.0-52.0 per cent moisture, 30.0-45.0 per cent FDM). LMPSM is often referred to as Pizza cheese, which is consumed fresh or after a brief period (5-15 days) of ageing (Badem and Ucar, 2016) [4]. The natural LMPSM cheese exhibits change in its functionality during its refrigerated storage. This translates into the consumer observing varying functionality of cheese (depending on its age), when used as pizza topping. Contrary to this, analogues cheeses are reported to be more stable to changes in their functionality during their refrigerated storage as compared to natural cheeses (Kiely *et al*., 1991, Jana and Upadhyay, 2001) [18, 16].

Nowadays, people are quite selective about the food they eat; they want to consume healthy product having low calorie, low cholesterol and preferably containing polyunsaturated fats and those fortified with essential vitamins and minerals. Manufacture of 'tailor-made' cheese analogues can have all of these nutritional traits, over and above the functional properties such cheese is expected to possess. Cheese analogue of any defined composition and nutritive value can be 'tailor-made' as per the demand and whims of the consumers; even the functionality can be modified as per the food restaurants specifications.

Unlike conventional Mozzarella cheese (made using starter culture technique) which requires long time of manufacture (~ 6-7 h), involves skill and requires ageing of cheese for obtaining the desired functionality on pizza, the manufacturing process (viz., by direct fabrication) of analogue cheese is quite short (i.e. ~ 30 min), hardly requiring any skill and can be prepared without resorting to use of starter culture and with few exceptions, rennet too. Since analogue cheeses can be made using cheaper ingredients (viz., vegetable oil, vegetable protein sources, starches, etc.), the product can be made available at a cheaper rate, without compromising on its quality (Chavan and Jana, 2007) [6].

A cheese factory utilizing dried rennet casein (RC)/acid casein (AC) will be able to prepare cheese of uniform quality day to day through use of commercially available casein powder of consistent composition. Casein has a very good shelf life at ambient temperature owing to low moisture (maximum 12.0 per cent) and fat content (maximum 2.0 per cent fat on dry matter) (FSSA, 2017) [11]. A byproduct such as casein can fetch a good price, if it is prepared to suit the manufacture of cheese analogue.

Cheese analogues are being produced commercially especially in developed countries. However, the production techniques for cheese analogues are mostly patented (Badem and Ucar, 2016) [4]. Some Indian manufacturers (e.g. Mahaan Proteins, Kosikalan; Modern Dairies, Karnal) of casein and caseinates are exporting such specialized value-added ingredients to countries abroad for manufacture of cheese analogues.

The major protein source in partial or dairy based analogue cheese is RC, AC, blend of RC and AC as well as Na-caseinate, Ca-caseinate and blend of Na/Ca-caseinates (Nishiya *et al.*, 1989a; Ennis and Mulvihill, 1999; Jana and Upadhyay, 2001; Sherkat and Walker, 2002; Guinee *et al.*, 2004; Mizuno and Lucey, 2005; Shah *et al.*, 2010; Sharma, 2012; Soni, 2014) [21, 9, 16, 28, 12, 19, 26, 27, 29]. AC contains relatively lower mineral content (i.e. about 2.5 per cent) as compared to RC (i.e. about 7.5 per cent). Such differences in the ash content translate to greater protein content in AC in relation to RC (Sarode *et al.*, 2016) [25]. Since the properties of casein are modified as a result of change in the manufacturing protocol of the specific casein being prepared, use of such protein ingredients in cheese analogue preparation would have a bearing on the functional properties of cheese. Rennet is present in RC, while AC is devoid of it. The mineral content of RC is much greater than that of AC (Soni, 2014) [29]. The pH of the two casein products is also different (about 5.66 vs. 6.07 in case of AC and RC respectively) (Jana and Upadhyay, 2001; Sharma, 2012) [16, 27].

The proximate cost of AC (Rs. 425/kg) and RC (Rs. 500/kg) is also important from financial point of view. When both the caseins are blended together, the resultant cost can be reduced.

2. Materials and methods

Acid casein (87.61% protein) and rennet casein (81.63% protein) were procured from M/s. Mahaan Protein Ltd., Kosikalan, Uttar Pradesh. Specialty palm kernel oil (partly hydrogenated fat) based vegetable fat (Code No. DFR) was procured from M/s. Kamani Oil Industries Pvt. Ltd., Mumbai, having an average melting point of 32°C. Anhydrous citric acid; calcium chloride, dehydrate; tri-sodium citrate, dehydrate; di-sodium hydrogen orthophosphate, dihydrate and lecithin were obtained from M/s. Loba Chemie Pvt. Ltd., Mumbai. Pre-gelatinized starch (Pregenil XT) was supplied by M/s. Madhu Hydrocolloids Pvt. Ltd., Ahmedabad. 'Tata' brand vacuum-evaporated salt manufactured by M/s. Tata Chemicals Ltd., Mumbai was obtained from local market. Natural cheese flavouring (Mozzarella cheese bud—No.

1036) paste was obtained from M/s. Adare Food Ingredients Pvt. Ltd., Vitthal Udyognagar, Gujarat. Fresh pre-baked pizza loaves was obtained from a local bakery in Anand, Gujarat. Natural Mozzarella cheese, prepared from milk on the same day as Mozzarella cheese analogues were prepared, was obtained from Vidya Dairy, Anand.

2.1 Preparation of Mozzarella cheese analogue

Acid casein based Mozzarella cheese analogue (ACMCA) was prepared as per the process standardized by Jana and Upadhyay (2001) [16] while rennet casein based Mozzarella cheese analogue (RCMCA) as well as rennet and acid casein based Mozzarella cheese analogue (ARCMCA) (rennet casein:acid casein, 3:2) were prepared as per the process standardized by Shah *et al*. (2010) [26] with minor modifications. The process used is described as under:

Casein powder or blend of casein powders (i.e.AC or RC or their admixture), common salt, pre-gelatinized starch, cheese flavouring and calcium chloride were added to hot (80°C) potable water containing emulsifying salt or the mixture of emulsifying salts. After part acidification with lactic acid solution (1:10 w/v of water), vegetable fat (@ 15%) in melted condition was added to the casein based dough and subsequently acidified to desired pH using the previously prepared lactic acid solution. The final dough formed was heated to 80°C for 3 min, shaped in to ball form, allowed to cool to ambient temperature followed by refrigerated (7±1°C) storage. A Hobart food processor (M/s. Hobart Corp. Canada – Model No. N 50) operating at three different speeds was used to blend the ingredients to form a dough and a SS kettle was used for heating while addition of vegetable fat. During experimentation, 1.5 kg of cheese analogues, ACMCA, RCMCA and ARCMCA each, were prepared for each treatment under study. The experiment was replicated four times. The formulation of Mozzarella cheese analogues is depicted in Table 1.

Table 1: Formulation of MCA made using two protein sources and their blend

Ingredients, %	ACMCA[1]	RCMCA[2]	ARCMCA[3]
Vegetable fat	15.00	15.00	15.00
Rennet casein	--	23.00	13.30
Acid casein	21.30	--	8.90
Tri-sodium citrate	0.90	2.25	2.75
Disodium hydrogen phosphate	1.60	0.75	--
Lecithin	0.15	--	--
Citric acid	0.18	0.60	0.50
Calcium chloride	0.36	--	--
Pre-gelatinized starch	2.00	2.00	2.00
Cheese flavouring	3.00	3.00	3.00
Common salt	1.10	1.10	0.90
Water	54.41	52.30	53.65

ACMCA & RCMCA – MCAs made using acid casein and rennet casein; ARCMCA – MCA made using blend of acid casein and rennet casein (6:4, w/w); 1 – Jana and Upadhyay (2001) [16]; 2 – Sharma (2012) [27]; 3 – Soni (2014) [29].

3. Result and discussion

3.1 Cost assessment of mozzarella cheese analogue

To assess the economic feasibility of MCA manufacture as against the production of NMC, an exercise was carried out wherein various technical and economic aspects were examined.

A plant producing 100 kg of MCA per day was considered reasonably satisfactory.

3.1.1 Raw materials cost

The raw materials cost for preparing 100 kg each of MCAs (i.e ACMCA, RCMCA and ARCMCA) is depicted in Table 2.

Comparison of raw materials cost reveals that ACMCA had the least cost (Rs. 148.00 per kg) among all the analogues, mainly due to lower price of AC (Rs. 425.00 per kg) as compared to RC (Rs. 475.00 per kg). RCMCA was the costliest (Rs. 160.50 per kg) owing to use of RC alone as the protein source; cheese ARCMCA had intermediate cost (Rs. 153.40 per kg) owing to use of blend of RC and AC.

The raw materials cost for preparing RCMCA and ARCMCA (RC:AC – 3:2, w/w), using vegetable fat were Rs. 182.70 and Rs. 175.65 per kg of product respectively (Soni, 2014) [29] while the raw materials cost of RCMCA was computed at Rs. 142.50 per kg (Sharma, 2012) [27]. The difference in the raw materials cost of analogues could be ascribed to the difference in the existing rate of major ingredients used, viz. Soni (2014) [29] reported the cost of RC and AC to be Rs. 550.00 and Rs. 480.00 per kg product respectively. Sharma (2012) [27] had taken cost of RC to be Rs. 380.00 per kg.

Jana (1998) reported that the raw materials cost of ACMCA made using vegetable fat blend was 63.20 per cent lower than that of NMC. In their case, both NMC and acid casein was prepared by the researcher and cost aspects calculated on that basis.

Table 2: Raw materials cost for producing 100 kg each of Mozzarella cheese analogues

Ingredients	Cost/kg (`)	ACMCA		RCMCA		ARCMCA	
		Rate of addition (%)	Amount (`)	Rate of addition (%)	Amount (`)	Rate of addition (%)	Amount (`)
Speciality vegetable fat	95	15.00	1425	15.00	1425	15.00	1425
Rennet casein	475	0.00	0	22.40	10640	13.30	6318
Acid casein	425	22.00	9350	0.00	0	8.90	3782
Tri-sodium citrate	500	0.90	450	2.25	1125	2.75	1375
Disodium hydrogen phosphate	510	1.60	816	0.75	383	0.00	0
Lecithin	2000	0.15	300	0.00	0	0.00	0
Citric acid	250	0.27	67	0.60	150	0.50	125
Calcium chloride	200	0.36	72	0.00	0	0.00	0

Pre-gelatinized starch	250	2.00	500	2.00	500	2.00	500
Cheese flavouring	1200	1.50	1800	1.50	1800	1.50	1800
Common salt	17	1.10	19	1.10	19	0.90	15
Water	0	55.12	0	54.40	0	55.15	0
Raw material cost/100 kg (`)			14799		16042		15340
Raw material cost/kg (`)			147.99		160.42		153.40

* ACMCA & RCMCA – MCAs made using acid casein and rennet casein; ARCMCA – MCA made using a blend of acid casein and rennet casein (6:4, w/w); NMC – Natural Mozzarella cheese.

3.1.2 Cost of utilities

Table 3 and 4 shows the heat energy required for processing and the electricity usage in the preparation of 100 kg MCA respectively. The water requirement has been assumed to be three times the quantity of product handled in case of MCA.

Table 3: Heat energy required during processing in producing 100 kg of Mozzarella cheese analogue

S. No.	Processing aspects	Energy (k.cal.) required in preparing cheese
1.	Pre-heating of water to 80°C	2182.25
2.	Pre-heating fat	117.00
3.	Maintaining temperature of cheese slurry in Hobart blender	56.40
4.	Processing in cheese kettle	1080.00
5.	Total heat energy utilized (k.cal.)	3425.65
6.	Steam requirement for MCA (kg)	6.36

Table 4: Electricity required for preparing 100 kg of Mozzarella cheese analogue

S. No.	Equipment	Motor H.P.	Total working hours	Units (kWh/day)
1.	Hobart mixer	5.00	2.00	7.46
2.	Cheese kettle	21.50	0.50*	8.02
3.	Packaging machine	0.50	3.00	1.12
4.	Refrigerated cabinet	0.75	14.00	7.83
Total Units				24.43
Lighting, etc. @ 15.0 % of total units				3.66
Actual electricity requirement for 100 kg MCA				28.09

*MCA was manufactured in cheese kettles in two lots (50 kg each)

3.1.3 Overhead cost

The overhead cost involving direct wages to the employees for a plant producing 100 kg MCA per day is provided in Table 5. The overhead cost amounted to Rs. 18.12 per kg of MCA.

The overhead cost was computed at Rs. 12.20 and Rs. 14.00 per kg of MCA by Sharma (2012) [27] and Soni (2014) [29] respectively. The higher overhead cost in the present study is due to improved existing rates for labour.

Table 5: Works overhead cost per day for producing 100 kg Mozzarella cheese analogue

S. No.	Employee	Number(s)	Salary per day (Rs.)	Cost per day (Rs.)
1.	Officer	1	1200.00	1200.00
2.	Labour			
	Skilled	1	314.00	314.00
	Unskilled	1	298.00	298.00
Total				Rs. 1812.00

The cost of steam, electricity and water was computed at Rs. 0.21, 2.11 and 0.15 per kg MCA. The total utilities cost arrived at was Rs. 2.47 per kg of MCA (Table 3). MCA prepared using RC and plastic cream required utility cost to the tune of Rs. 1.83 per kg (Shah 2008), while Sharma (2012) [27] computed utility cost of Rs. 1.84 per kg of MCA prepared using RC and vegetable fat. Soni (2014) [29] reported utility cost of Rs. 1.79 per kg of MCA prepared using a blend of RC and AC (6:4, w/w) and vegetable fat.

The utility cost arrived at in the present study is comparatively higher due to higher existing rates for fuel, electricity unit and water.

Table 6: Comparative appraisal of the final cost per kg of Mozzarella cheese analogues

Ingredients	Cost/kg (`)	Cheese analogue made using		
		Acid casein	Rennet casein	Casein blend*
		Amount (`)	Amount (`)	Amount (`)
Raw materials cost		14799	16042	15340
Works overhead cost		1812	1812	1812
Utilities cost				
a) Steam	3.2/kg	21	21	21
b) Electricity	7.5/Unit	211	211	211
c) Water	50.0/kL	15	15	15
Packaging cost	10.0/kg	1000	1000	1000
Cost/100 kg cheese		17858	19101	18399

Cost/kg cheese	178.58	191.01	183.99

* ACMCA & RCMCA – MCA made using acid casein and rennet casein, ARCMCA – MCA made using casein blend comprised on Rennet casein: Acid casein (60:40 w/w), NMC – Natural Mozzarella cheese.

3.1.4 Packaging cost

The packaging cost involving packaging material (for 1 kg block each) and the sealing cost for the cheese is provided in Table 6. The packaging cost (Rs. 1000/100 kg cheese) is similar to that reported by Shah (2008), Sharma (2012) [27] and Soni (2014) [29].

3.1.5 Total cost

The total cost of the cheese analogues are shown in Table 6. The total costing was Rs. 178.60, Rs. 191.00 and Rs. 184.00 for ACMCA, RCMCA and ARCMCA respectively for products prepared in the present study. Sharma (2012) [27] computed the cost of RCMCA to be Rs. 166.48 per kg while Soni (2014) [29] reported cost of Rs. 201.45 and 208.50 per kg of ARCMCA and RCMCA respectively. The difference in the cost is due to the change in the existing rates of raw materials, fuel, electricity, water and labour.

The raw materials cost was 82.87, 83.98 and 83.37 per cent of the total product cost for ACMCA, RCMCA and ARCMCA respectively. Sharma (2012) [27] and Soni (2014) [29] reported the share of raw materials cost to be 85.56 and 87.62 per cent of the total cheese cost respectively for RCMCA; the raw materials cost was 87.19 per cent of the total cost for ARCMCA (Soni, 2014) [29].

Currently, a reputed brand of natural Mozzarella cheese used in the current study is being sold at Rs. 363 per kg. It may be assumed that the profit incurred on the sale of such cheese was 20.0 per cent of the sales price (i.e. Rs. 73.00 per kg); the cost price of Mozzarella cheese comes to Rs. 290.00 per kg. Therefore, the cost of ACMCA, RCMCA and ARCMCA was 38.42, 34.14 and 36.56 per cent cheaper respectively as compared to NMC.

Conclusion

Hence, it can be concluded that MCA prepared from different types of casein and their combination is much cheaper than natural Mozzarella cheese but the functional and rheological properties as well as sensory characteristics may not be matching with natural cheese. Therefore, it is advisable to use the mixture of natural and analogue Mozzarella cheese in order to reduce cost without affecting quality.

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