

Cheeses of Turkey: 1. Varieties ripened in goat-skin bags

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(Received 15 December 2006 – Accepted 2 February 2007)

Abstract – More than ten types of Tulum cheese are produced in Turkey. Tulum cheese has a white or cream color, a high fat content, a crumbly semi-hard texture and a buttery pungent flavour. The most popular of these cheeses is Erzincan Savak Tulum which is produced mainly in the eastern region of Turkey and is now produced in many factories; it has higher economic value than the other varieties of Tulum cheese. Some aspects of this cheese are reviewed, i.e., milk used, thermal treatment of the milk, rennet and starters, manufacturing technology, chemical composition and biochemical changes during ripening. The second most widely consumed type of Tulum cheese is Izmir Brined Tulum, the technology and characteristics of which are also discussed in some detail. The other varieties of Tulum cheese are consumed mainly in the region where they are produced and it is very difficult to find them throughout Turkey. They are not well characterized and are discussed only briefly. However, there is increasing interest at present in the manufacture of the other types of Tulum cheese and they have gained an economic value.

Turkish cheese / Tulum cheese / goat's skin bag / ripening

摘要 – 土耳其干酪：1. 在羊皮袋中成熟的干酪品种。在土耳其有 10 余种 Tulum 干酪。Tulum 干酪呈白色或乳白色、脂肪含量高、酥脆、半硬质、有奶油味和辛辣味。在 Tulum 干酪中最受欢迎的是 Erzincan Savak Tulum 干酪，这种干酪主要产于土耳其的东部地区并已经工厂化生产；与其他种类的 Tulum 干酪相比，这种干酪的价值较高。对 Erzincan Savak Tulum 干酪的研究已有文献报道，如原料奶的种类、原料奶的热处理、凝乳酶和发酵剂、干酪的制造技术、成熟期间的化学组成和生化性质变化等。第二种消费量最大的 Tulum 干酪是 Izmir Brined Tulum 干酪，关于这种干酪的制造技术和特性也有过文献报道。其他种类的 Tulum 干酪主要在产地消费，在土耳其的其他地区很难发现这些干酪，而且关于这些干酪的文献报道也非常少。因此，对其他类型 Tulum 干酪的制造技术和特性的研究引起了人们广泛的关注，以期通过研究和推广获得更高的经济效益。

土耳其干酪 / Tulum 干酪 / 羊皮袋 / 成熟

Résumé – Fromages de Turquie : 1. Variétés affinées en poches en peaux de chèvre. Plus de dix sortes de Tulum sont produits en Turquie. Ce fromage d'une couleur crème ou blanche possède une teneur élevée en matière grasse (gras sur sec > 50 %), une pâte semi-dure de texture grumelleuse et une saveur de beurre piquante. Le plus populaire de ces fromages est le Erzincan Savak Tulum,

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produit principalement dans la région de l'est de la Turquie et fabriqué par plusieurs usines ; son poids économique est plus important que celui des autres variétés de Tulum. Les caractéristiques de ce fromage sont passées en revue, i.e., le lait employé, le traitement thermique du lait, les levains et la présure utilisés, la technologie de fabrication, la composition chimique et les modifications biochimiques au cours de l'affinage. La seconde variété largement consommée est le fromage de type Izmir Brined Tulum (en saumure), dont les caractéristiques sont également présentées en détails. Les autres variétés de Tulum sont principalement consommées dans leurs régions de production et ne sont pas rencontrées dans toute la Turquie. Ces derniers ne sont pas aussi bien caractérisés et ne sont présentés que brièvement. Cependant, l'intérêt pour la fabrication de ces autres types de Tulum est croissant et leur valeur économique augmente.

fromage turc / Tulum / peau de chèvre / affinage en poche

1. INTRODUCTION

Many cheese varieties which are produced only in restricted geographical areas of the world are consumed locally in large quantities. More than 50 varieties of cheese are produced in Turkey, but only three of them, Beyaz, Kasar and Tulum cheeses, are widely popular. The production of Tulum cheese was 10 000 tonnes in 2004 (data from the Turkish Statistical Institute, Ankara). Its production has increased greatly in recent years and it is produced in a number of cheese plants.

Tulum cheese is produced throughout Turkey except in Thrace, but mainly in East and Central Anatolia regions. In general, there are two types of Tulum cheese, *Erzincan Savak Tulum* which is produced mainly in the eastern region of Turkey and *Izmir Brined Tulum* ("*Izmir Salamurali Tulum peyniri*" in Turkish) which is produced in the western region. *Erzincan Savak Tulum* is made in the mountains and plateaux of Erzincan, Erzurum, Tunceli, Bingol and Elazig and East Anatolian regions by the Savak tribe and was ripened originally in tulum for at least three months in caves. When people say "Tulum cheese" in Turkey, they imply *Erzincan Savak Tulum*. The other types of Tulum cheese and their production areas (in parenthesis) are: Cimi (Antalya), Divle (Karaman), Kargi (Cankiri, Corum), Isparta (Isparta), Afyon (Afyon), Selcuklu (Konya), Giresun (Giresun) and Tomas or Cokelek (Eastern provinces of Anatolia) cheese. In the present paper, emphasize is mainly on *Erzincan Savak Tulum* cheese, but some definitions and manufacturing processes for other types of Tulum cheese are given also.

2. DEFINITION

Tulum cheese has a white or cream colour, a high fat content, and a crumbly, semi-hard texture; it is dispersible in the mouth and has a buttery and pungent flavour [44]. The name "*tulum*" means "goat's or sheep's skin bag" in Turkish, in which the curds are packaged and ripened. Goat's skin bags are stronger than sheep's skin bags and tulum are permeable to water and air due to their porous structure. In the past, the use of a tulum for cheese packaging was probably due to the absence of alternative materials but nowadays, wooden, plastic or earthenware containers are also used for the ripening of Tulum cheese; hardened plastic barrels are the most popular for this purpose.

Studies on Tulum cheese are very limited, but some researchers have focused on this variety during the last decade [7, 14–17, 20, 22, 27, 39, 40, 43–45, 48, 49, 54]. These researchers have concentrated on the chemical and microbiological status of Tulum cheeses sold in Turkish markets. Few studies are available on the effects of different packaging materials on the microbiological and chemical characteristics of Tulum cheese. The microbiological quality of Tulum cheese ripened in goat's skin or polyethylene bags were compared by Guven and Konar [27]. Sengul et al. [55] studied the effect of packaging materials (wooden box, goat's skin or polyethylene bags) on the microbiology of Tulum cheese during ripening. The use of different types of milk (cow's, ewe's or goat's milk) in the manufacture of Tulum cheese was compared by Guven et al. [29] who reported that the type of milk significantly influenced the



Figure 1. Piling of the cotton bags filled curds.

microbiology of Tulum cheese during 210 d of ripening. Sengul and Cakmakci [53], who used polyethylene bags or wooden boxes as alternatives to a tulum, emphasized that the packaging material affects the chemical and microbiological qualities of Tulum cheese and recommended further studies to identify the best material. Although cheesemaking from raw milk continues, the use of pasteurized milk and a starter culture for Tulum cheese was recommended by Bostan and Ugur [8] and Sengul et al. [55].

The above studies related only to the composition and microbiological status (hygienic aspects) of Tulum cheese. Some authors [26, 27, 55] have pointed out that ripening in tulums or polyethylene bags significantly influenced the chemistry and microbiology of tulum cheese during ripening. Consumer preference studies indicated that cheese ripened in tulums is superior to cheese ripened in polyethylene bags. Due to increasing interest in traditional cheeses in Turkey and in many other countries, further studies are needed to understand better the technology, chemistry, biochemistry and microbiology of these cheeses.

3. MANUFACTURING PROCEDURE FOR TULUM CHEESE

3.1. General

Traditionally, the cheese is made from raw ewe's milk without a starter culture; the

milk is acidified by its native microflora. Home-made calf rennet is used at 35 °C. The coagulum is cut into pieces (approximately 1 cm³) and transferred into cotton bags for whey drainage at about 20 °C for 24 h. The curds are pressed by piling the cotton bags on top of each other (Fig. 1), with regular turning. Stacking of the curd at this temperature allows the development acidity (pH drops below 6.0) and increases whey drainage. Following this step, the blocks of curd are broken by hand into the pieces the size of peas (Fig. 2) and dry-salted, kneaded and transferred to the cotton bags which are piled on top of each other and turned regularly for 10 days. Afterwards, the curds are tightly filled into a goat-skin bag, "tulum" (Fig. 3) or a plastic barrel (Fig. 4).

3.2. Inputs for cheesemaking

3.2.1. Milk

Ewe's milk, mainly, is used for Tulum cheese production but, some goat's milk (less than 20%, v/v) may be mixed with sheep's milk. The milk is not pasteurized in the traditional method, but pasteurization (65 °C for 20 min) is used in industrial production [58].

3.2.2. Starter culture

The development of acidity in the curds is achieved by the indigenous flora of the



Figure 2. Breaking of the curds by hand into the pieces the size of peas.



Figure 3. Filling of the curds into a goat skin bag through neck.



Figure 4. Filling of the curds into a plastic barrel.

raw milk used. However, yoghurt is mixed with the curds (approximately 1.5–2.0 kg yoghurt is added per 100 kg curd) prior to filling into tulum by some manufactures, but this practice is not common. Indigenous lactic acid bacteria in Tulum cheese have been isolated and identified recently by various researchers [19, 47, 49, 54]. A few

groups have attempted to develop a suitable starter culture for Tulum cheese, but different combinations of starter species have been recommended, e.g., *Lb. casei* subsp. *casei* plus *Lc. lactis* subsp. *lactis* [7], *Ent. faecalis* plus *Lc. lactis* subsp. *lactis* plus *Lb. casei* subsp. *casei* [35] or *Lc. lactis* subsp. *lactis* plus *Lc. lactis* subsp. *cremoris* plus *Leu.*

mesenteroides subsp. *cremoris* [5]. Further studies are needed to select the best starter combination and the optimum level of addition.

3.2.3. Coagulant

Home-made rennet is the coagulant usually used for Tulum cheese but industrially-produced rennet (calf or microbial) has been used recently in some factories. The home-made rennet is prepared by a traditional method as follows: cleaned young calves' stomachs are air-dried while shaded from the sun, cut into slices, and then placed in whey containing *ca.* 10% (w/v) NaCl. After 1–2 weeks, the rennet extract (prepared by blending macerated stomach slices in the NaCl solution) is clarified (filtered) using a cotton cloth and the filtrate is used as a coagulant. The strength of the home-made rennet is fairly low in comparison to industrially-produced rennet. To the authors' knowledge, no study has been conducted to compare proteolytic and lipolytic potential of these two rennets for Tulum cheese.

3.2.4. Salting

The salting procedure used for Erzincan Savak Tulum is similar to that used for Cheddar. NaCl is added at a level of 2–3% (w/w) to the pressed curds after breaking into pieces the size of peas and the curds and salt are mixed in a vat. For Izmir Brined Tulum cheese, blocks of curd, 7 × 7 × 7 cm, are firstly dry-salted on a salting table and the surface of the blocks is sprinkled with



Figure 5. A goat skin bag filled with curds.

coarse salt the size of rice grains, for 1–2 d. Every 2 h, the blocks are turned and the surface is dry-salted again. This operation is repeated until the cheese has a total acidity of about 1.8% lactic acid. Then, the blocks are put into tinned cans which are filled with 12% (w/v) NaCl brine.

3.2.5. Packaging

Goat skin bags are the traditional material for packaging of Tulum cheese (Fig. 5). Nowadays, the cheese is ripened in hardened plastic barrels (Fig. 6) with a capacity



Figure 6. Plastic barrels filled with curds.



Figure 7. Piercing the plastic barrel with a metal borer called “bizi”.

of *ca.* 10–20 kg, like that of a goat’s skin bag. However, some quality problems are encountered with cheese ripened in plastic, such as softening and whey separation. Therefore, when filled with cheese, the bottom of plastic barrels are pierced (5–6 holes with 3 mm diam) with a metal borer called a “*bizi*” in Turkish to allow excess water to drain from the cheese during ripening (Fig. 7). In goat skin bags, excess water from the cheese drains off through the pores in the skin during ripening. Although goat skin bags have some difficulties in use, the cheese develops a stronger flavour than when ripened in plastic. Goat skin bags are obtained from goats during the autumn season. Meat or fat residues on the skin are scraped off and the skin is sprinkled with fine salt and folded over. After a week, the skin is opened and dried while shaded from the sun and kept away from sun light, moisture and heat. Prior to use, the skin is submerged in water and tears are repaired. All openings of the skin should be closed except the neck, through which the curd is filled.

4. CHEMISTRY OF TULUM CHEESE DURING RIPENING

The chemical composition of Tulum cheese varies widely due to lack of a standardized production protocol, the type of milk used and ripening conditions. From a compositional point of view, only the moisture level is restricted by legal regulations

(the moisture content should not exceed 40%, w/w) for Tulum cheese according to Turkish Standard 3001 [3]. In practice, the moisture content of Tulum cheese is in the range 40–45% (w/w) [22, 26, 40, 51]. The moisture content of young cheese is high, but the cheese loses moisture during ripening due to the porous structure of the skin bag [5, 28, 31, 61]. The cheese has an acidic taste; its pH is 4.8 to 5.2, with some fluctuations during ripening [29, 31, 53]. It may change with the progress of proteolysis, since the pH increases due to proteolysis products such as ammonia. The pH of cheese sometimes decreases to 4.3–4.4 [26, 32] which causes significant changes in the gross composition of the cheese due to changes in the solubility of colloidal calcium near the isoelectric point of casein. So, the casein matrix shrinks and expels serum. The skin bag allows exudation of the serum during ripening. Therefore, when the cheese is filled into hardened plastic barrels, the barrels are pierced with a needle (3 mm in diam); otherwise, a number of defects occur such as body softening, over-sour and bitter taste. The salt content (% w/w) of the cheese can increase during ripening due to the loss of moisture. A salt-in-dry matter in Tulum cheese of 3–6% (w/w) is acceptable. A low level of salt may favour proteolysis in the cheese. Tulum cheese contains a high level of fat; ripened cheese has a fat-in-dry matter of 55.3% [26], 51.6% [22] or 58.9 [48]. Full-fat cheese is preferred

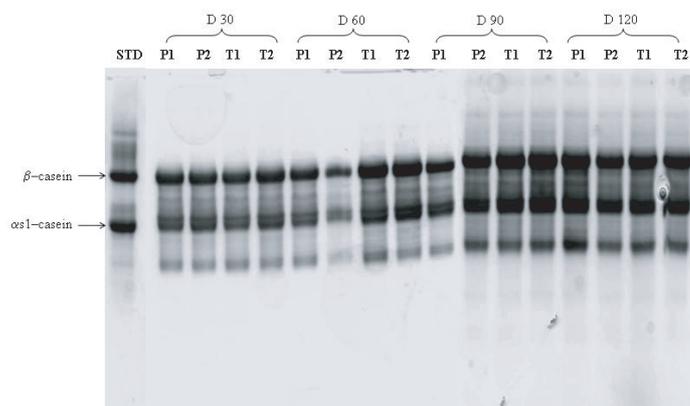


Figure 8. Urea-PAGE electrophoretograms of the pH 4.6-insoluble fraction of Tulum cheeses ripened in plastic or goat's skin bags for 30, 60, 90 and 120 d. STD = sodium caseinate; P and T: refer to the cheeses ripened in plastic or tulum materials, respectively; 1 and 2: refer to the cheeses manufactured in the dairies 1 and 2, respectively (from Hayaloglu et al. [31], reprinted by permission of Journal of Dairy Science).

by consumers. Low-fat variants of the cheese are used for the production of a Blue-type mould-ripened cheese (Kumlu) [30]. Mendil [46], who studied the mineral content of Tulum cheese, found the mean levels of Ca, Mg, K and Na to be 442, 10, 36.2 and 395.7 mg·100 g⁻¹, respectively.

5. BIOCHEMISTRY OF TULUM CHEESE DURING RIPENING

Tulum cheese was originally ripened in caves for at least 3 months, but nowadays rooms operating at 4–6 °C are used for ripening. During ripening, many chemical changes occur, including protein breakdown, fat hydrolysis and catabolism of lactose and lactate. Proteolysis is the most complex and important phenomenon in the ripening of Tulum cheese. The ripening period for Tulum cheese is longer than for other typical Turkish cheeses such as Beyaz peynir and Kasar. The cheese is ripened for at least 3 months in a cold room, but it is usually consumed after about 6 mo, and the ripening period may be as long as 1 year.

5.1. Proteolysis

Extensive proteolysis occurs during ripening. The low pH of Tulum cheese ensures a high level of residual rennet in the curd, and this is favourable for the initial hydrolysis of α_{s1}-casein [21]. Tulum cheese is traditionally manufactured using home-made rennet which contains many enzymes other than chymosin, and the characteristic Tulum cheese flavour can be obtained only by the use of home-made rennet. The level of water-soluble nitrogen (WSN) in Tulum cheese increases continuously during ripening and the reported level of WSN is typically 26% of total nitrogen ranging from ~18 to ~31% [22, 26, 28, 42, 48]. Tarakci et al. [56] reported that the addition of black cumin (*Nigella sativa*) to Tulum cheese increased the level of WSN. Urea-polyacrylamide gel electrophoresis (urea-PAGE) and reversed-phase high performance liquid chromatography (RP-HPLC) were used to monitor the degradation of proteins and peptides during Tulum cheese ripening [31]. Figure 8 shows the urea-PAGE electrophoretograms of the pH 4.6-insoluble fraction of Tulum cheese during 120 d of

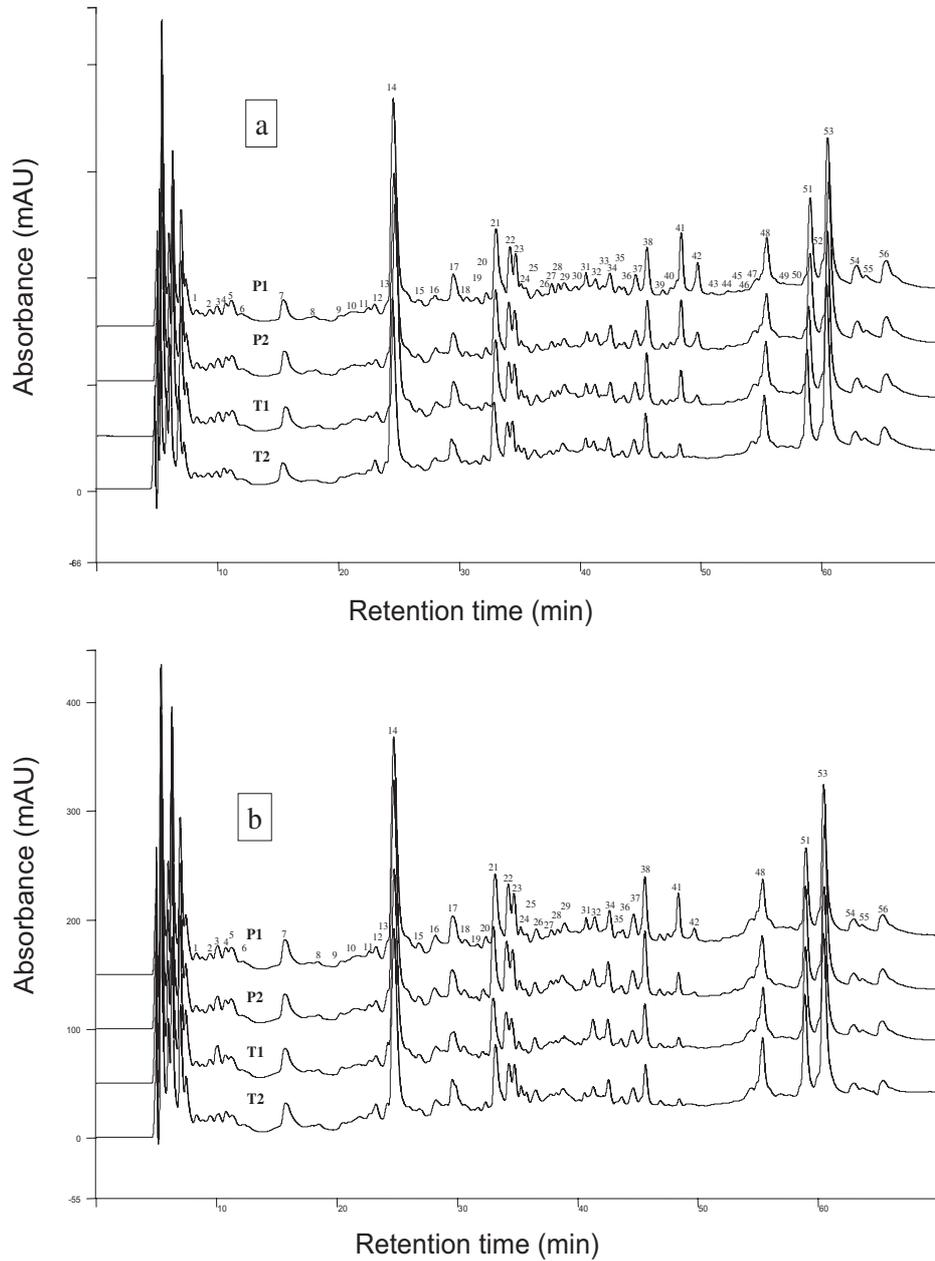


Figure 9. Reversed phase-HPLC peptide profiles of the pH 4.6-soluble fraction from Tulum cheeses ripened in plastic or goat's skin bags for 30 (a), 60 (b), 90 (c) and 120 (d) d. P and T: refer to the cheeses ripened in plastic or tulum materials, respectively; 1 and 2: refer to the cheeses manufactured in the dairies 1 and 2, respectively (from Hayaloglu et al. [31], reprinted by permission of Journal of Dairy Science).

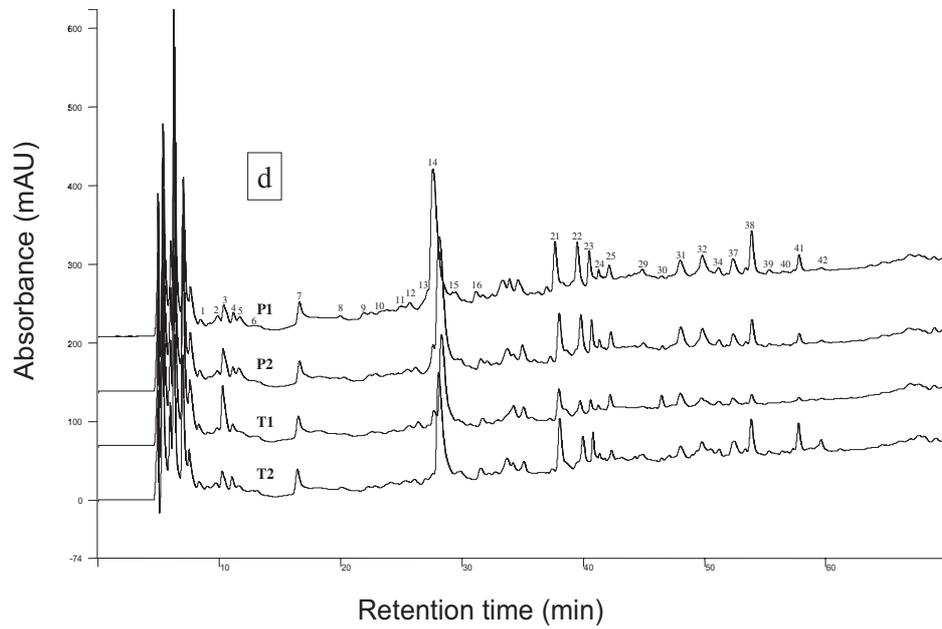
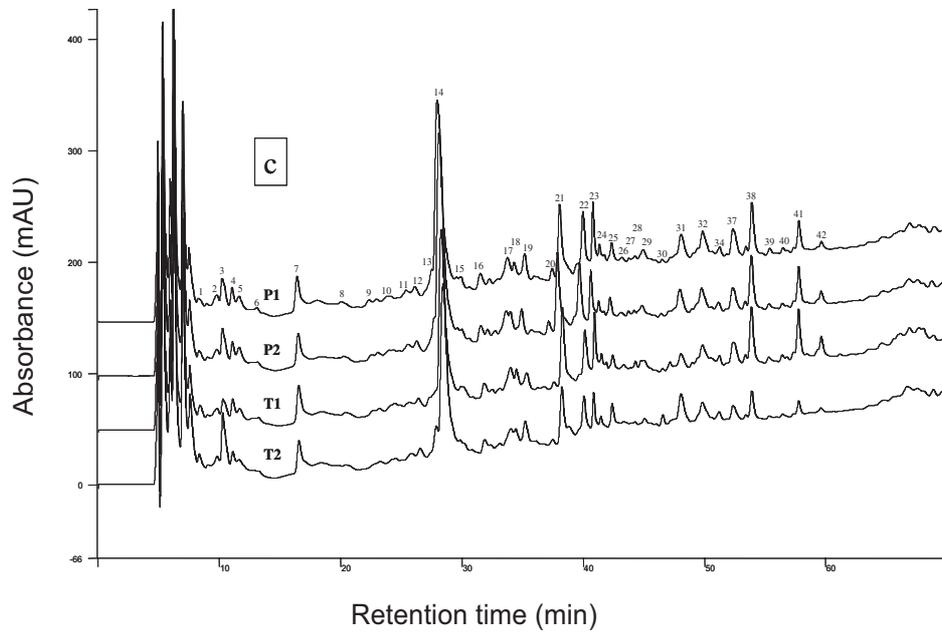


Figure 9. Continued.

Table I. Concentrations¹ of individual amino acids in Tulum cheese made from cow's, ewe's or goat's milk during ripening².

Amino acid	Ripening time (mo)											
	1			3			5			7		
	Cow	Ewe	Goat	Cow	Ewe	Goat	Cow	Ewe	Goat	Cow	Ewe	Goat
Asp	8.29	6.12	11.20	24.28	18.68	25.34	44.56	26.68	31.86	85.41	76.38	75.39
Thr	9.28	9.48	10.02	16.54	28.04	18.40	32.88	21.44	41.82	50.58	64.47	42.96
Ser	8.61	4.54	4.73	7.62	13.44	11.06	19.88	13.12	18.48	33.36	34.44	17.19
Glu	17.45	16.33	16.54	31.66	51.96	41.04	69.78	46.50	69.40	130.80	115.59	92.73
Pro	3.55	4.06	5.73	15.34	14.98	17.20	39.50	17.40	27.84	72.21	54.69	20.88
Gly	3.45	3.26	2.45	4.74	9.44	5.06	8.70	6.24	9.18	15.03	17.64	9.18
Ala	4.00	3.58	4.25	6.58	10.68	10.00	17.10	11.80	15.02	27.75	31.98	13.44
Val	10.45	10.55	11.95	20.16	30.64	25.36	43.78	28.56	40.52	36.12	82.83	37.53
Met	2.53	3.01	3.13	5.02	9.62	6.70	11.66	9.38	14.36	21.21	28.29	24.60
Ile	4.27	5.05	4.16	7.70	14.88	10.50	16.00	12.01	15.48	29.55	30.99	14.88
Leu	13.29	15.48	4.16	22.66	45.54	31.44	54.80	41.42	59.28	61.38	113.97	38.76
Tyr	2.39	4.16	5.16	8.04	12.08	11.42	19.60	4.58	4.80	29.85	19.20	11.61
Phe	6.98	7.94	7.64	14.22	24.02	16.02	28.88	19.34	30.34	57.81	60.24	46.74
Lys	13.20	17.54	14.17	23.82	51.02	37.56	64.80	40.28	46.04	113.13	110.94	40.74
His	4.59	4.93	5.81	10.46	11.38	12.48	22.22	12.14	5.78	37.62	36.81	17.40
Arg	3.57	6.87	5.94	3.76	12.18	20.22	30.02	11.50	ND ³	79.74	1.05	7.05
Total	114.90	122.90	127.04	222.30	358.58	299.80	523.46	322.40	430.24	879.27	879.51	511.08

¹ mg 100·g⁻¹ of cheese.² From Guven [25].³ Not detected.

ripening. Although α_{s1} -casein was hydrolyzed rapidly, much of the β -casein remained intact at the end of ripening. The RP-HPLC peptide profile of pH 4.6- and 70% (v/v) ethanol-soluble or -insoluble fractions were also monitored by Hayaloglu et al. [31], but peptides have not been isolated and characterized. The peptide profile (pH 4.6-soluble) of the cheeses changed as ripening progressed and some new peptides with intermediate retention times (30 to 50 min) were found (Fig. 9). However, some peptides, in particular those that eluted in the hydrophobic region (50 to 70 min) disappeared after 90 d of ripening, probably due to further hydrolysis of these peptides to shorter peptides or free amino acids.

Individual amino acids in Tulum cheese made from cow's, ewe's or goat's milk

were studied by Guven [25] during 210 d of ripening (Tab. I). The concentration of free amino acids increased continuously during ripening and Glu, Leu and Lys were the principal amino acids in the cheeses made from different types of milk. Ala, Val and Phe were also present at high levels in Tulum cheeses ripened in goat's skin or plastic bags for 30 or 120 d [31]. Guven [25] emphasized that the use of different types of milk for the production of Tulum cheese influenced the amino acid profile in the matured cheeses, although no substantial differences were found in unripened Tulum cheese.

Biogenic amines, including tryptamine, phenylethylamine, putrescine, cadaverine, histamine, tyramine, spermidine and spermine were detected in Tulum cheese by

Table II. Mean values¹ of free fatty acids in Tulum cheese (control sample) during ripening².

Days	C _{2:0}	C _{3:0}	C _{4:0}	C _{6:0}	C _{8:0}	C _{10:0}	C _{12:0}	C _{14:0}	C _{16:0}	C _{18:0}	C _{18:1}	Total
1	1.58	0.30	1.07	1.12	1.92	2.96	4.79	9.04	30.74	7.14	24.74	85.39
15	3.02	0.30	2.96	1.52	1.70	4.01	5.76	13.69	37.83	10.48	36.71	117.78
30	5.92	0.41	3.87	2.00	1.91	5.86	7.84	16.35	41.11	11.64	39.11	136.02
60	6.98	0.74	4.56	2.52	2.94	6.01	9.95	20.49	47.77	15.25	46.86	164.06
90	7.75	1.10	8.56	3.96	4.12	8.01	10.56	26.15	50.86	18.15	49.30	188.52

¹ mg·100 g⁻¹.² From Yilmaz et al. [61].**Table III.** Fatty acids composition¹ in Tulum cheese ripened in goat-skin bags or under brine².

Ripening condition	C _{4:0}	C _{6:0}	C _{8:0}	C _{10:0}	C _{12:0}	C _{14:0}	C _{16:0}	C _{18:0}	C _{18:1}	C _{18:2}	C _{18:2}
Skin bag (n = 7)	2.24	2.22	2.20	3.92	4.04	11.86	30.16	9.08	22.00	1.72	1.76
Brine (n = 9)	3.02	2.36	2.19	4.54	3.65	11.53	29.76	9.64	23.18	1.81	1.48

¹ Expressed as free fatty acids as % of total fatty acids.² From Akalin et al. [2].

HPLC; tyramine was the principal amine [16]. These authors claimed that the concentration of amines increased with age, probably due to proteolysis. Oner et al. [49] also found tyramine at higher levels (0 to 329.0 mg·kg⁻¹) than tryptamine (0.32 to 40.4 mg·kg⁻¹) in 20 samples of Tulum cheese.

5.2. Lipolysis

Free fatty acids (FFAs) make significant contributions to the typical flavour of Tulum cheese (a slight rancid and pungent flavour) and the FFAs serve as precursors for the formation of several sapid compounds. Guler and Uraz [22] found a high level of lipolysis in 20 commercial samples of Tulum cheese. These authors reported an acid degree value (ADV) of 8.0 mg·KOH g⁻¹ cheese fat. Other workers [42, 61] reported much lower ADV values (about 4.4 and 5.5 mg·KOH g⁻¹ cheese fat, respectively) for 90 d old Tulum cheese. Therefore, controlled lipolysis is needed for Tulum cheese as in some Swiss and Italian cheeses. Yil-

maz et al. [61] studied the effect of a microbial lipase (Piccantase A) on lipolysis of Tulum cheese during ripening. They showed that the addition of lipase increased the concentrations of FFAs and the typical Tulum cheese flavour. The levels of FFAs in Tulum cheese (control sample) during 90 d of ripening are given in Table II. The acids (C_{2:0} to C_{10:0}) constituted the small proportion of total volatile acids in Tulum cheese, but are major contributors to typical flavour. Acetic (C_{2:0}) and capric (C_{10:0}) were the principal volatile acids in Tulum cheese. The most abundant FFAs were C_{16:0} (palmitic acid) and C_{18:1} (oleic acid). Higher levels of C_{16:0} (5600 mg·kg⁻¹ cheese) and C_{18:1} (5000 mg·kg⁻¹ cheese) were found in 20 samples of Tulum cheese [22]. Minor differences in the levels of FFAs were found between the samples of Tulum cheese ripened in skin bags or in brine (Tab. III) [2]. The total free fatty acids (as g oleic acid·100 g⁻¹ of cheese fat) in Tulum cheese made from sheep's milk was 5.4% at the early stage of ripening and increased during ripening to 10.2% [25].

5.3. Volatiles

There are limited data on volatile flavour compounds in Tulum cheese. The first study was performed by Hayaloglu et al. [31] who identified about 100 volatiles in 90-d old Tulum cheese using solid-phase microextraction (SPME) and GC-MS. The volatile compounds included 11 acids, 16 esters, 12 methyl ketones, 7 aldehydes, 22 alcohols, 7 sulfur compounds, 6 terpenes and 19 miscellaneous compounds. The main components were short-chain fatty acids, 2-butanone, diacetyl and primary alcohols, including ethanol. Ethyl esters, acetaldehyde, 2-propanal, 3 methyl butanal, 2-butanol, 2-pentanol, phenethyl alcohol, dimethyl disulfide, dimethyl sulphone, α -pinene, carane and *p*-cymene were present at considerable levels in 90-d old Tulum cheese [31]. Further studies should be undertaken to understand how the type of milk, starter, enzyme, packaging material, ripening conditions, etc., affect the final quality of Tulum cheese.

6. MICROBIOLOGY OF TULUM CHEESE DURING RIPENING

6.1. Microbial flora

Raw ewe's milk is used in the manufacture of traditional Tulum cheese; consequently, the natural microflora of the milk used and the hygienic conditions during manufacture strongly influence the microbiology of Tulum cheese during ripening. The total bacterial count (log cfu·g⁻¹ cheese) is high in Tulum cheeses at various ripening stages, e.g., 9.35 [40], 8.51 [7], 9.32 [45], 9.25 [15] or 7.44 [48]. Coliform bacteria were also found in Tulum cheese at (log cfu·g⁻¹ cheese) 4.04 [35], 6.51 [45], 3.23 [48] or 6.99 [51]. Efe and Heperkan [17], who studied 60 samples of Tulum cheese, found that 72% of the cheese samples contained coliform bacteria which are present in the cheeses at the highest levels at the beginning of ripening due to the use of raw milk; their numbers decreased with age [10, 27, 29, 31, 52, 55]. The numbers of coliform bacteria in 150-d old Tulum

cheese made from raw ewes' milk was < 2 [27] or < 1 log cfu·g⁻¹ cheese [31]. Bostan [7] and Bostan and Ugur [8] claimed that the coliform bacteria disappeared from raw ewes' milk Tulum cheese after 60 d of ripening. It can be concluded that the counts of coliform bacteria decrease with age in Tulum cheese. Yeasts and moulds are present at high numbers in Tulum cheese, e.g., 7.00 [40], 6.27 [45], 6.01 [7], 6.56 [15], 5.46 [51] or 4.83 [48] log cfu·g⁻¹. These values are quite high according to the Turkish Standards for Tulum cheese [3] which allow up to 2 log cfu·g⁻¹ yeasts and moulds. The numbers of yeasts and moulds increase during ripening and do not decrease at the end of ripening [27, 31, 52, 55]. This increase is probably due to the porous structure of the skin bag. In addition, yeasts and moulds can not be prevented by the use of pasteurized milk, because the cheese mass is continuously in contact with air. To the authors' knowledge, the yeasts isolated from Tulum cheese have not yet been identified to species level.

6.2. Lactic acid bacteria

Recently, some studies have been performed on the natural flora of Tulum cheese and showed that lactic acid bacteria (LAB) were the predominant flora during ripening. Several studies on the identification of LAB in Tulum cheese have been reported [9, 19, 47, 49, 54]. Bostan et al. [9], who produced Tulum cheese from raw cows' milk, isolated 684 strains of LAB during ripening. The authors reported that *Lc. lactis* subsp. *lactis* and *Ent. faecalis* were predominant during the initial stage, but *Ent. faecium*, *Lc. lactis* subsp. *lactis*, *Lb. casei* and *Lb. plantarum* predominated during the later stages of ripening. Low numbers of leuconostocs and pediococci were also isolated from the cheese. Sengul and Cakmakci [54] reported that the majority (92%) of isolates were *Lactobacillus* spp. (*Lb. parabuchneri* and *Lb. bifementans* were the predominant species). However, Oner et al. [49] reported that *Lactobacillus* spp. represented 49% of the total isolates from 20 samples of Tulum cheese. Furthermore, Erdogan and Gurses [19] reported that the dominant microorganisms of Tulum cheese were *Enterococcus*

(53%) and *Lactobacillus* (23%) at the end of ripening (4 months). Oksuztepe et al. [47] identified 783 LAB isolated from Tulum cheeses during ripening for 90 d. The authors reported that lactococci were predominant during the first month of ripening but were replaced by lactobacilli towards the end of ripening. The predominant species were *Lb. casei* subsp. *casei*, *Lb. plantarum*, *Lc. lactis* subsp. *lactis*, *Lc. lactis* subsp. *cremoris*, *Leu. mesenteroides* subsp. *cremoris* [47]. Cakmakci et al., who studied the LAB profile of Tulum cheese during 9 months of ripening, found the highest counts of LAB at the beginning of ripening and their numbers decreased during later stages. Different genera, including *Enterococcus*, *Lactobacillus*, *Streptococcus*, *Lactococcus* and *Pediococcus* were found in unripened cheese but *Lactobacillus* spp. predominated during the early stage of ripening. As ripening progressed, the *Streptococcus* and *Lactococcus* spp. disappeared, *Enterococcus* spp. remained unchanged and *Lactobacillus* and *Enterococcus* spp. were the predominant species in mature Tulum cheese (data not published).

6.3. Pathogens

Since Tulum cheese is manufactured from raw milk under non-hygienic conditions, some hazardous pathogens, such as *Listeria monocytogenes*, *Staphylococcus aureus* and *Salmonella* spp. may be present and cause health problems for consumers. Efe and Heperkan [17], who studied 60 samples of Tulum cheese, isolated *Staphylococcus aureus* and *E. coli* Type I from 97% and 70% of the samples, respectively. The counts of *S. aureus* were high at the beginning of ripening ($6.08 \log \text{cfu} \cdot \text{g}^{-1}$) and decreased to $4.98 \log \text{cfu} \cdot \text{g}^{-1}$ at 4 months [4]. Bostan and Ugur [8] detected *S. aureus* in raw milk Tulum cheese during 90 d of ripening and were $4.0 \log \text{cfu} \cdot \text{g}^{-1}$ at 90 d. According to Digrak et al. [15], who investigated the survival of some pathogens in 17 samples of Tulum cheese, the mean $\log \text{cfu} \cdot \text{g}^{-1}$ counts of *S. aureus*, *Salmonella* spp., *Bacillus* spp. and *Listeria monocytogenes* were 4.54, 3.00, 5.65 and 4.51, respectively. *L. monocytogenes* and *Salmo-*

nella spp. were isolated from 4.8 and 2.4%, respectively, of 250 samples of Tulum cheese by Colak et al. [13]. However, Cetinkaya et al. [12] did not detect *L. monocytogenes* in 52 samples of Tulum cheese. *Salmonella* spp. was not detected by Ozalp et al. [50] and Kivanc [39].

7. OTHER VARIETIES OF TURKISH CHEESE RIPENED IN A SKIN BAG

7.1. Izmir Brined Tulum

Izmir Brined Tulum is manufactured from raw ewes' milk or mixtures of ewes' and goats' or cows' milk in the Aegean region of Turkey, especially Izmir, Aydin, Manisa, Mugla and Denizli and is very popular in other regions of Turkey. Its production method resembles that for normal Tulum cheese, with minor differences. During manufacture, the curds are heated by adding hot water at 40–50 °C and transferred to cloth bags for draining and then pressing. Sometimes, the curds containing whey are hung and the whey drained off for 3–5 h. Then, the curds are cut into blocks with a knife and salted (as mentioned in Sect. 3.2.4). Some brine is absorbed by the cheese curds during ripening and the rest leaks out through skin bag. Izmir Brined Tulum has holes, 2–3 mm diam [36, 58, 59]. Bedel and Kilic [6], who produced Izmir Brined Tulum with or without a starter culture, emphasized that the use of starter increased the level of WSN in the cheese (35.7% instead of 17.9%) and shortened the ripening period (from 90 to 45 d). Koca and Metin [41] successfully used starter bacteria, including *Lc. lactis* subsp. *lactis*, *Lc. lactis* subsp. *cremoris*, citrate-positive *Lc. lactis* subsp. *lactis*, *Leu. cremoris*, *Lb. helveticus*, *Lb. casei* and *Ent. faecium* in the manufacture of Izmir Brined Tulum. The chemical composition of Izmir Brined Tulum was reported to be 61.8 or 57.1% dry matter, 26.6 or 28.7% fat, 27.4 or 21.3% protein, 5.8 or 5.9% salt by Eralp [18] and Yaygin [60], respectively. In another study, a typical Izmir Brined Tulum produced without a starter culture had 51.2% dry matter, 43.6% fat-in-dry matter, 3.9% salt, 5.2 pH,

5.0 WSN (% of TN) at 1 d of ripening; these values changed to 49.6%, 42.4%, 7.1%, 5.1 and 17.9%, respectively, after 90 d of ripening [6].

7.2. Divle

Divle, which is made from ewes' milk, is a variety of Tulum cheese; "divle" is the name of a natural cave, 232 m in length and 55 m deep, in Konya province. The temperature in the cave is 4–5 °C and the relative humidity is $80 \pm 5\%$ [59]. The production method for Divle resembles that for normal Tulum cheese, but with some differences. After curd formation, the curd was broken and cooked at 55 °C (the temperature is increased gradually) for 5 min and transferred to cloths and pressed for 24 h. The curd is cut into blocks using a knife and dipped in cold water to remove whey. Again, the curd is placed in the cloths for whey drainage and broken into pea-size pieces by hand and dry-salted at a level of 2.5% (w/w). Finally, the curds are filled into goat-skin bags, packed tightly and transported to Divle caves for maturation for 4–6 months [33, 57]. Mean values for composition are: moisture 42.9%, fat 21.3%, salt 3.0% and pH 5.4 [33].

7.3. Karin Kaymagi

Karin Kaymagi, which is manufactured in the eastern region of Turkey, may be considered as a Tulum cheese variety, but it is ripened in tripe "karin" in Turkish. The level of fat in the cheese is quite high. The milk used in its manufacture is mainly ewes' milk, but sometimes cows' milk is mixed with it when ewes' milk is insufficient. If skimmed milk is used in production, a certain amount of cream or butter is added to the curds before filling into the tripe. The production method for the cheese is similar to that for Tulum cheese except that the cheese is ripened in a cleaned tripe. Prior to use, the tripe is cleaned carefully by a mechanical method and held in boiling water for about 10 min. After being filled with curd, the tripe (containing *ca.* 3 kg of curd) is tied up and pressure (about 100 kg for a tripe) is applied for about 3 d to remove

excessive whey from the curd. Finally, the tripe is hung from the ceiling of the ripening room (70–80% relative humidity and 5–10 °C) and ripened for at least 2–3 months [11]. The chemical and microbiological status of the cheese was studied by Cakmakci et al. [11]; moisture, fat, protein, salt contents and total acidity were 30.9%, 39.0%, 19.0%, 4.4% and 1.0%, respectively. Microbial counts were quite high, i.e., the total bacteria, 7.69–9.89 log cfu·g⁻¹, coliforms, 0–4.80 log cfu·g⁻¹ and yeasts and moulds, 3.30–6.61 log cfu·g⁻¹. The high number of these microorganisms may be due to use of raw milk in the production and the unhygienic conditions during manufacture and ripening.

7.4. Antalya Cimi

Cimi is made from goats' milk in the Alavada plateau (altitude 2000–3000 m), by villagers from "Cimi" in Antalya. The cheese, packed in goats' skin, like Tulum cheese, is ripened in natural caves at 0–4 °C and about 90% relative humidity in the Alavada plateau. The cheese has a special flavour and aroma originating from the natural plant flora of the plateau. The cheese is ripened until the end of October for 3–4 months and marketed in the big cities of Turkey like Istanbul, Ankara, Izmir and Antalya [37]. The chemical composition of 4 mo-old Cimi is: moisture 39.0%, fat 30.6%, salt 3.4%, protein 22.8%, total acidity (as g lactic acid·100 g⁻¹ cheese) 2.0%, pH 5.1, WSN (as % of TN) 16.0% [37]. Kilic et al. [38] studied the fatty acids composition in 3-month old Cimi, which were (as % of total fatty acid): C₄: 7.94, C₆: 1.67, C₈: 2.85, C₁₀: 8.81, C₁₂: 4.03, C₁₄: 9.46, C₁₆: 24.32, C₁₈: 13.43, C_{18:1}: 32.89, C_{18:2}: 1.04, C_{18:3}: 1.59. The total free fatty acid (as mg oleic acid·100 g⁻¹ cheese fat) in the cheese was 9.9 mg·100 g⁻¹ at the early stage of ripening and increased during ripening to 14.3 mg·100 g⁻¹ [38].

7.5. Selcuklu

Selcuklu is produced in the Konya province of Turkey and it is ripened in artificial

casings for 1 month at about 7 °C and 75% relative humidity. Pasteurized cows' milk or a 1:1 mixture of cows' and ewes' milks are used in the manufacture with a lactic starter culture composed of *Lc. lactis* subsp. *lactis* and *Lc. lactis* subsp. *cremoris*. After cutting of the curd and salting at a level of 2% (w/w), the curds are filled into artificial casings which contain about 1 kg of Selcuklu [57]. There have been no studies on the chemical composition and other properties of Selcuklu.

7.6. Tomas

The name means skin or leather in Greek. Tomas is also called cokelek, serto or dorak in various cities of Turkey [1]. This type of cheese is produced in the eastern region of Turkey. Prior to production, the milk is converted to yoghurt which is churned for butter production. After butter separation, the remaining material (the defatted yoghurt, named "ayran" in Turkish) is heated and the proteins precipitated and used for the manufacture of Tomas, sometimes after adding cream (to increase its nutritional value) and yoghurt (as a starter). The mixture is mixed 5–6 times at weekly intervals and filled into skin bags or tripes and ripened until some moulds grow on its surface [59]. The moulds are strains of *Penicillium roqueforti* [23]. Lactic acid bacteria are predominant in Tomas, especially *Lc. lactis* subsp. *lactis*, *Lc. lactis* subsp. *cremoris*, *Streptococcus thermophilus*, *Lb. delbrueckii* subsp. *bulgaricus*, and *Lb. plantarum* [24]. Keven et al. [34], who studied 20 samples of cokelek, found the chemical composition to be (mean values): dry matter 38.3%, fat 5.1%, salt 3.8% and pH 5.0.

8. CONCLUDING REMARKS

In addition to the above varieties, some other cheeses are important locally. Although no published data on their chemical composition are available, their production and ripening procedures resemble Tulum cheese. These varieties are produced in Afyon, Kayseri, Isparta, Konya, Antalya, Izmir, Tokat, Giresun, Erzurum and Kars

and they are named after the city where they are produced. Due to limited data on these cheeses, the chemical, biochemical and microbiological status should be determined during ripening. Hygienic conditions during manufacture and ripening are needed to obtain a reliable product. Pasteurization should be included in the manufacturing protocol and the cheese quality may be improved by using starter cultures based on microorganisms isolated from traditionally produced cheeses. Compositional variations between cheeses produced by different manufacturers are responsible for lack of standard manufacturing protocol; standardization in the manufacturing process could solve this problem.

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