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Microbiological aspects of goat's milk. A Public Health Laboratory Service survey*

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SUMMARY

In a 12-month survey (June 1982–May 1983) 41 laboratories examined 2493 samples of goat's milk for colony counts and the presence of pathogens. The statutory tests for cow's milk were also applied.

Surface counts of $< 10^5$ organisms per ml of raw milk were given by 79% of samples at 37 °C and by 76% at 22 °C. There were < 100 coliforms per ml in 71% of samples, < 10 *Escherichia coli* per ml in 91%. *Staphylococcus aureus* was not detected in countable numbers in 96% of samples. Only one isolation of campylobacter was made and two of *Yersinia enterocolitica*. Salmonella was not detected in 2462 samples. The methylene blue test was carried out on 2368 samples and 86·7% were deemed satisfactory. No sample was Brucella ring-test-positive.

Experiments on the survival and growth of six food poisoning organisms in stored goat's milk showed that *Bacillus cereus*, *Staph. aureus*, *Salmonella typhimurium* and *Y. enterocolitica* survived quite well and multiplied at the higher storage temperature of 30 °C. *Clostridium perfringens* only increased 10- to 100-fold while *Campylobacter jejuni* did not grow.

The results of the survey indicate that any problems with goat's milk relate to poor hygiene during production rather than transmission of organisms from the goat herself.

INTRODUCTION

Most milk consumed in the United Kingdom comes from the cow, whereas in other parts of the world the water buffalo and the domestic goat are important dairy species. There is, however, a growing demand in this country for supplies of goat's milk and its products which has resulted in an increase in the goat population and distribution of such milk. Goat's milk is alleged to be superior in nutritional quality to that of the cow and is used by people allergic to cow's milk.

* The following Public Health Laboratory Service laboratories participated: Bath, Brighton, Bristol, Cambridge, Cardiff, Chelmsford, Chester, Dorchester, Epsom, Exeter, Gloucester, Guildford, Hull, Ipswich, Leeds, Leicester, Lincoln, Liverpool, London (Central Middlesex, Dulwich, Food Hygiene, Whipps Cross), Maidstone, Manchester, Middlesbrough, Newcastle, Nottingham, Oxford, Plymouth, Poole, Preston, Reading, Salisbury, Sheffield, Shrewsbury, Stoke, Taunton, Truro, Watford and Wolverhampton. The Microbiology Department, Worcester Royal Infirmary also participated.

It is richer in fat than ordinary cow's milk, has a higher concentration of the simple (caproic, caprylic, capric and lauric) fatty acids but is lacking in folic acid and carotenoid pigments. The greater amounts of short-chain fatty acids may make caprine milk more digestible. The Manchester Business School estimated the British market for goat's milk in 1981 to be 80000 gallons a year (*Observer*, 6 Sept. 1981).

While the distribution chain for cow's milk is well established and almost all (97 % in England and Wales) is sold in a heat-treated form, this is not true for goat's milk. Production is still very much a cottage industry, with hand milking and local retailing through farm gate sales and health food shops, although there are some large herds milked by machines, with a wider area of distribution (Cousins, 1980). Most of the milk is sold untreated either in a liquid or frozen form, with a few processors producing a dried product.

Since most goat's milk is sold raw and its production is increasing there is concern about microbiological quality in some areas, in particular where it has been recommended as an alternative for infants allergic to cow's milk (Tripp *et al.* 1979; Taitz & Armitage, 1984). Although a number of infections associated with the consumption of goat's milk have been described from various parts of the world (Mocquot & Béjambes, 1959) reports are rare in the United Kingdom.

Public Health laboratories are sometimes asked to carry out microbiological examinations of goat's milk, and this raises a number of questions. There is no statutory test for goat's milk. The Milk (Special Designation) Regulations (1977) apply only to milk from the cow, and there is little published information on the microbiology of goat's milk. What tests should be carried out? Are the statutory tests for cow's milk suitable?

A preliminary survey was carried out in February 1981 among the 52 regional and area laboratories of the Public Health Laboratory Service. A questionnaire was distributed asking for information relating to the number, type and source of goat's milk examined between 1978 and 1980, the reasons for sampling and laboratory tests undertaken. A total of 1520 samples had been examined by 43 laboratories in the 3-year period, all samples were raw and mainly from farm gate sales and health food shops. Only six laboratories had been requested to examine goat's milk because of possible association with illness. Most laboratories (34/43) had performed the methylene blue test as described for cow's milk and the Brucella ring test. Some retail samples had high bacterial counts, exceeding 10^6 organisms per ml, and some contained *Escherichia coli* and *Staphylococcus aureus* (P.H.L.S., unpublished data).

The results of this preliminary survey showed the need for a more detailed study of goat's milk using a standard set of tests.

MATERIALS AND METHODS

Organization

Forty-one laboratories participated in a one-year survey which began in June 1982 and was completed in May 1983. A detailed protocol was prepared and circulated to all laboratories; methods were standardized as far as possible, but some flexibility was allowed to fit in with the media and methods familiar to the staffs of individual laboratories. Arrangements were made with local environmental

health departments for their officers to obtain samples of goat's milk. A standard report form used in the P.H.L.S. for food samples was used for recording results, which included the nature of the sample (i.e. raw/pasteurized, liquid/frozen), type of container, whether from a producer or retailer, the place of sampling and the condition of storage at the place of sampling.

Examination of milk samples

Laboratories were asked to carry out a full examination on each sample, except for tests for *Yersinia enterocolitica* and the Brucella ring test, which were optional. The required tests were the following.

(i) Enumeration of total bacteria – surface colony count by the surface drop method (ICMSF 1978) on 5% horse blood agar medium in duplicate, incubated aerobically at 37 °C for 48 h and 22 °C for 72 h.

(ii) Enumeration of coliforms and *E. coli* – by the 3-tube most probable number method (ICMSF 1978), using MacConkey broth or the medium in routine use at the time in individual laboratories, with tenfold dilutions of the milk up to 10^{-4} (the most commonly used alternative medium was minerals-modified glutamate broth). Tubes showing acid and gas after incubation at 37 °C for up to 48 h were confirmed to contain *E. coli* by subculturing to demonstrate the production of indole and gas at 44 °C.

(iii) Enumeration of *Staph. aureus* – surface colony count on a selective agar e.g. Baird-Parker, Kranep, mannitol salt or phenolphthalein phosphate polymyxin agars at 37 °C. Suspect colonies were confirmed as *Staph. aureus* by coagulase and/or DNase production. If present in large numbers, 10^5 per ml or more, cultures were sent to the appropriate reference laboratories for phage typing and enterotoxin testing.

(iv) Enrichment culture for salmonella – by the standard ISO method (ISO, 1975) but with a choice of selenite and/or tetrathionate broth as secondary enrichment and brilliant green and/or deoxycholate citrate agars as plating media. Suspect colonies were confirmed as salmonella by biochemical and serological tests, and any isolates sent to the reference laboratory for typing.

(v) Enrichment culture for campylobacter – 10 ml milk were added to 30 ml selective enrichment broth (Preston medium, Bolton & Robertson, 1982), incubated at 42 °C for 24 h, subcultured onto a selective agar medium, Preston medium (Bolton & Robertson, 1982) or Skirrow medium (Skirrow, 1977) and incubated at 42 °C in an atmosphere of reduced oxygen for 48 h. Typical colonies were confirmed as *Campylobacter* spp., and sent to the appropriate laboratory for biotyping and serotyping.

(vi) Enrichment culture for *Y. enterocolitica* – 25 ml of milk were added to 225 ml 1% buffered peptone water (Edel & Kampelmacher, 1969), incubated at 4 °C and subcultured at 1, 2 and 3 weeks to LSU agar (Juhlin & Ericson, 1961) or an agar medium of choice, e.g. Schiemann CIN medium (Oxoid CM 653 plus selective supplement SR 109) or deoxycholate citrate agar, and incubated at 30 °C for 48 h. Suspect colonies were confirmed by biochemical tests and sent to the reference laboratory for serotyping.

(vii) The methylene blue, phosphatase and Brucella ring tests – as laid down for cow's milk in the Milk (Special Designations) Regulations (1977).

(viii) Presence of *Bacillus cereus* – no special test was included for this organism

Table 1. *Samples of goat's milk examined and tests carried out in P.H.L.S. survey*

Type of sample or test carried out	Number of samples (%)				
Raw					
Liquid	1020	(40·9)			
Frozen	1112	(44·6)	2477	(99·3)	
Not stated	345	(13·8)			
Pasteurized					2493 (100)
Liquid	1	(< 0·1)			
Frozen	13	(0·5)	14	(0·6)	
Not stated					
Frozen	2	(< 0·1)	2	(< 0·1)	
Count at 37 °C			2480	(99·5)	
Count at 22 °C			2355	(94·5)	
Coliform estimation			2440	(97·9)	
E. coli estimation			2425	(97·3)	
Count of *Staph. aureus*			2490	(99·9)	
Count of *B. cereus*			1348	(54·1)	
Enrichment for salmonella			2462	(98·8)	
Enrichment for *Campylobacter* spp.			2453	(98·4)	
Enrichment for *Yersinia* spp.			2144	(86·0)	
Methylene blue test			2368	(95·0)	
Brucella ring test			2133	(85·6)	

but laboratories were asked to record the presence of *B. cereus* on the surface colony count plates. If present in large numbers, an isolate was sent to the reference laboratory for serotyping.

Most laboratories used the methods laid down in the protocol; alternative methods or variations were recorded on the forms returned to the collating laboratory.

Survival and growth of pathogenic bacteria in goat's milk

A number of experiments were also carried out in the Food Hygiene Laboratory to determine the ability of *B. cereus*, *Staph. aureus*, *Clostridium perfringens*, *Salm. typhimurium*, *C. jejuni* and *Y. enterocolitica* to survive and grow in goat's milk held at various temperatures. Low (10^2–10^3 orgs/ml) and high (10^5 orgs/ml) concentrations of the organism in goat's milk were incubated at 4, 22 and 30 °C for up to 72 h. Subcultures were made and counts carried out on a selective agar medium relevant to each test organism after 0, 6, 24, 48 and 72 h storage at each temperature. For *Y. enterocolitica* the storage period at 4 °C was extended to 1 week and for *C. jejuni* an additional temperature of 43 °C was included.

RESULTS

The total number and type of samples examined by the 41 laboratories are listed in Table 1. The number of samples examined per laboratory ranged from 1 to 324, with eight laboratories each examining more than 100 samples. The required tests were carried out on 95% or more of submitted samples and the optional *Y. enterocolitica* and Brucella ring tests were carried out on the majority (86%). The number of samples in which *B. cereus* was sought is low because this test was

Table 2. *Source of samples of goat's milk*

Source	Type of sample (%) Frozen	Liquid	Not stated	Total
Farm/farm shop	187 (16·6)	299 (29·3)	58 (16·8)	544 (21·8)
Smallholding	92 (8·2)	270 (26·4)	14 (4·1)	376 (15·1)
Health food shop	415 (36·8)	20 (2·0)	21 (6·1)	456 (18·3)
Supermarket	77 (6·8)	3 (0·3)	5 (1·4)	85 (3·4)
Other retail	203 (18·0)	23 (2·3)	36 (10·4)	262 (10·5)
Other	145 (12·9)	381 (37·3)	83 (24·1)	609 (24·4)
Not stated	8 (0·7)	25 (2·4)	128 (37·1)	161 (6·5)
Total	1127 (45·2)	1021 (41·0)	345 (13·8)	2493 (100)

not included at the beginning of the survey; laboratories were asked to note the presence of this organism only when the survey had been in progress for 4 months (end of September 1982). As only 14 of the samples examined were pasteurized the results of the phosphatase test have not been included in the tables.

Type and source of sample

The type of sample examined by the 41 laboratories and the source from which they were obtained are given in Table 2. Most of the liquid samples came from farms, smallholdings and private households, whereas retail premises such as health food shops, supermarkets and grocery stores sold a frozen product. The type of container in which the milk was distributed was recorded for less than half the samples (46·5%); the most common was a plastic bag used for frozen milk. A number of laboratories commented that these plastic bags leaked when the milk was allowed to thaw. Other containers included waxed cartons and bottles. Most of the liquid samples were stored in refrigerators or chillers (49·9%) but a few (4·2%) were kept at ambient temperature. The storage conditions were not stated for almost half of these samples.

Bacterial counts: total bacteria, coliforms, Staph. aureus

The results of the main microbiological tests on raw goat's milk are given in Table 3. They show that 79% of samples gave surface colony counts of $< 10^5$ organisms per ml of raw milk at 37 °C and 76% at 22 °C, while 71% of samples contained < 100 coliforms per ml and 91% samples < 10 *E. coli* per ml. *Staph. aureus* was not detected in countable numbers in most samples (96% < 100/ml) and in only two samples did the number exceed 10^4/ml ($4{\cdot}5 \times 10^4$/ml and $1{\cdot}5 \times 10^6$/ml). The latter strain was shown by the reference laboratories to be phage type 6/47/53/54/75/83A/85+ and enterotoxin (A–F) negative.

Table 3 also gives an analysis of the bacterial count in relation to the type and condition of raw goat's milk sample. There was very little difference between the liquid and frozen samples. Eighty per cent of each type of sample contained $< 10^5$ organisms per ml, while those in which the condition was not stated had marginally higher counts (75% with $< 10^5$ organisms/ml).

Table 4 compares the microbiological condition of the raw goat's milk samples in relation to place of sampling. The samples obtained from supermarkets and

Table 3. *Microbiological condition of raw goat's milk*

Type of sample	Test	Number (%) samples with counts in range									Total samples	
		< 10	< 10^1–10^2	10^2–10^3	10^3–10^4	10^4–10^5	10^5–10^6	10^6–10^7	10^7–10^8	> 10^8		
Liquid	Surface	—	130 (13)	159 (16)	344 (34)	168 (17)	113 (11)	52 (5)	27 (3)	24 (2)	1017	2464
Frozen	colony	—	110 (10)	177 (16)	401 (36)	201 (18)	136 (12)	63 (6)	15 (1)	7 (1)	1110	
Not stated	count, 37 °C	—	53 (16)	44 (13)	85 (25)	71 (21)	37 (11)	28 (8)	18 (5)	1 (< 1)	337	
Liquid	Surface	—	159 (17)	135 (14)	270 (28)	160 (17)	.105 (11)	73 (8)	31 (3)	21 (2)	954	2341
Frozen	colony	—	156 (15)	143 (13)	341 (32)	199 (19)	131 (12)	76 (7)	16 (2)	16 (2)	1078	
Not stated	count, 22 °C	—	49 (16)	38 (12)	74 (24)	66 (21)	35 (11)	24 (8)	22 (7)	1 (< 1)	309	
Liquid	Coliform	529 (53)	158 (16)	91 (9)	132 (13)	63 (6)	16 (2)	12 (1)	0	—	1001	2424
Frozen	estimation	603 (56)	181 (17)	140 (13)	126 (12)	26 (2)	6 (< 1)	5 (< 1)	0	—	1087	
Not stated		190 (54)	39 (12)	43 (13)	43 (13)	17 (5)	1 (< 1)	3(< 1)	0	—	336	
Liquid	*E. coli*	881 (90)	53 (5)	23 (2)	20 (2)	5 (< 1)	0	0	0	—	982	2409
Frozen	estimation	1005 (93)	51 (5)	18 (2)	9 (< 1)	2 (< 1)	1 (< 1)	0	0	—	1086	
Not stated		296 (87)	22 (7)	14 (4)	7 (2)	1 (< 1)	0	1 (< 1)	0	—	341	
Liquid	*Staph. aureus*	—	983 (97)	22 (2)	10 (1)	4 (< 1)	0	0	0	0	1019	2474
Frozen	count	—	1058 (95)	23 (2)	24 (2)	4 (< 1)	0	1 (< 1)	0	0	1110	
Not stated		—	326 (95)	13 (4)	6 (2)	0	0	0	0	0	345	

Table 4. *Microbiological condition of raw goat's milk in relation to source of samples*

Source of sample	Test	Number (%) samples with counts in range: < 10	$< 10^1$–10^2	10^2–10^3	10^3–10^4	10^4–10^5	10^5–10^6	10^6–10^7	10^7–10^8	$> 10^8$	Total samples	
Farm/farm shop	Surface	—	67 (13)	91 (17)	180 (34)	86 (16)	61 (11)	26 (5)	11 (2)	13 (2)	535	
Smallholding	colony	—	47 (13)	62 (17)	123 (33)	69 (18)	43 (12)	16 (4)	9 (2)	5 (1)	374	
Health food store	count	—	43 (10)	53 (12)	159 (35)	83 (19)	70 (16)	29 (6)	8 (2)	3(< 1)	448	2309
Supermarket	37 °C	—	5 (6)	4 (5)	23 (27)	29 (34)	12 (14)	8 (10)	2 (2)	2 (2)	85	
Other retail		—	23 (9)	44 (17)	96 (37)	49 (19)	23 (9)	16 (6)	8 (3)	2(< 1)	261	
Other		—	74 (12)	102 (17)	214 (35)	100 (17)	62 (10)	34 (6)	13 (2)	7 (1)	606	
Farm/farm shop	*Staph. aureus*	—	447 (92)	25 (5)	13 (3)	3 (< 1)	0	0	0	0	488	
Smallholding	count	—	344 (92)	18 (5)	5 (1)	6 (2)	0	0	0	0	373	
Health food store		—	400 (94)	11 (3)	9 (2)	4 (1)	0	0	0	0	424	2228
Supermarket		—	83 (95)	3 (3)	1 (1)	0 (0)	0	0	0	0	87	
Other retail		—	242 (93)	7 (3)	4 (2)	5 (2)	0	2 (< 1)	0	0	260	
Other		—	533 (89)	33 (6)	14 (2)	16 (3)	0	0	0	0	596	
Farm/farm shop	*E. coli*	446 (90)	29 (6)	15 (3)	4 (< 1)	0	0	0	0	—	494	
Smallholding	estimation	343 (91)	17 (5)	6 (2)	5 (1)	4 (1)	0	0	0	—	375	
Health food store		399 (90)	27 (6)	8 (2)	6 (1)	2 (< 1)	0	0	0	—	442	2250
Supermarket		82 (96)	3 (4)	0	0	0	0	0	0	—	85	
Other retail		241 (93)	11 (4)	3 (1)	4 (2)	0	1(< 1)	0	0	—	260	
Other		532 (90)	32 (5)	13 (2)	16 (3)	1 (< 1)	0	0	0	—	594	

Table 5. *Methylene blue test and goat's milk – pass rate in relation to bacterial load*

Test	Proportion (%) samples passing with counts in range: < 10	10^1–10^2	10^2–10^3	10^3–10^4	10^4–10^5	10^5–10^6	10^6–10^7	10^7–10^8	$> 10^8$	Total
Surface colony count (37 °C)	—	296/297 (99·7)	364/366 (99·5)	761/799 (95·2)	366/426 (87·6)	182/266 (68·4)	52/129 (40·3)	10/47 (21·3)	3/25 (12·0)	2034/2355 (86·4)
Surface colony count (22 °C)	—	367/367 (100)	306/310 (98·7)	659/676 (97·5)	364/415 (87·7)	170/249 (68·3)	79/161 (49·1)	15/56 (26·8)	5/35 (14·3)	1965/2269 (86·6)
Coliform estimation	1266/1298 (97·5)	320/359 (89·1)	208/258 (80·6)	170/284 (59·9)	42/87 (44·8)	6/22 (27·3)	1/14 (7·1)	0	—	2013/2322 (86·7)
E. coli estimation	1861/2101 (88·6)	86/116 (74·1)	33/48 (68·8)	13/33 (39·4)	4/7 (57·1)	0/1 (0)	0/1 (0)	0	—	1997/2307 (86·6)
Staph. aureus count	—	1970/2262 (87·1)	46/55 (83·6)	29/39 (74·4)	6/8 (75·0)	0	1/1 (100)	0	0	2052/2365) (86·8)

health food shops were of slightly poorer microbiological quality, 24/85 (28 %) and 110/448 (25 %) respectively with colony counts at 37 °C of $> 10^5$ per ml compared with 18–20 % from other sources. However, the sample size from supermarkets was small compared to the other sources.

Presence of salmonella, Y. enterocolitica, *campylobacter and* B. cereus

Very few samples contained the specific pathogens. There was only one isolation of campylobacter (*C. jejuni* biotype 2, ampicillin-resistant) and two of *Y. enterocolitica* (serotypes 06,30 and 07). The sample which contained the *Y. enterocolitica* 06,30 was microbiologically very poor with a total count of 2×10^9 organisms per ml and a high level of coliforms and *E. coli*, and was a methylene blue failure. The samples containing the campylobacter and the other yersinia were better with total counts of $2{\cdot}5 \times 10^4$ and $8{\cdot}0 \times 10^3$ per ml respectively. However the campylobacter-positive sample contained $5{\cdot}0 \times 10^2$ *E. coli* per ml and the yersinia-positive sample $2{\cdot}0 \times 10^3$ *Staph. aureus*. Both samples passed the methylene blue test.

Of the 1348 samples examined for *B. cereus* only three yielded the organism at countable levels. One sample (total count $2{\cdot}2 \times 10^6$ organisms per ml) contained 120 *B. cereus* per ml while the other two (total counts $< 10^3$ organisms per ml) contained 80 *B. cereus* per ml.

Salmonellas were not found in any of the 2462 samples examined.

Methylene blue test

The methylene blue test was carried out on 2368 samples. Two thousand and fifty-four samples (86·7 %) were deemed satisfactory by the test and there was little difference in pass rate between liquid and frozen samples. Table 5 shows the correlation between the methylene blue test results and bacterial counts for all types of sample. The pass rate decreases as the number of organisms in the milk increases. However, some samples passed the test with counts exceeding 10^8 organisms per ml, whereas some samples with counts of < 100/ml failed the test. The methylene blue test is a measure of the activity of organisms present in the sample, not their numbers. The anomalies could therefore be explained by high counts of organisms with low deoxygenating activity or low counts of very active organisms.

It was thought that freezing the milk might influence the methylene blue test. A slightly greater proportion of frozen than liquid samples with high counts passed the test.

Relationship between surface colony count and levels of coliforms and E. coli

Table 6 shows the total counts on goat's milk compared with levels of coliforms and *E. coli*. The higher the surface colony count the higher the count of both coliforms and *E. coli*.

Brucella ring test

No samples were Brucella ring-test-positive although occasionally tests were difficult to read owing to the difference in fat globule size and distribution in bovine and caprine milk.

Table 6. *Relationship between surface colony count and levels of coliforms and* E. coli *in goat's milk*

Surface colony count, 37 °C	Number (%) of samples with levels of coliforms in range									
	< 10	10–10^2	10^2–10^3	10^3–10^4	10^4–10^5	10^5–10^6	10^6–10^7	$> 10^7$	Total*	
$< 10^2$	278 (94)	16 (5)	2 (< 1)	0	0	0	0	0	296	2429
10^2–10^3	301 (82)	51 (14)	13 (4)	3(< 1)	0	0	0	0	368	
10^3–10^4	494 (60)	172 (21)	95 (12)	54 (7)	1 (< 1)	0	0	0	816	
10^4–10^5	168 (39)	81 (19)	91 (21)	68 (16)	24 (5)	0	1(< 1)	0	433	
10^5–10^6	61 (22)	49 (17)	49 (17)	74 (26)	33 (12)	16 (6)	0	0	282	
10^6–10^7	17 (12)	8 (6)	19 (13)	58 (41)	26 (18)	5 (3)	10 (7)	0	143	
10^7–10^8	6 (10)	2 (3)	1 (2)	29 (49)	10 (17)	2 (3)	9 (15)	0	59	
$> 10^8$	2 (6)	1 (3)	2 (6)	15 (47)	12 (38)	0	0	0	32	
	Number (%) of samples with levels of *E. coli* in range									
	< 10	10–10^2	10^2–10^3	10^3–10^4	10^4–10^5	10^5–10^6	10^6–10^7	$> 10^7$	Total*	
$< 10^2$	293 (100)	0	0	0	0	0	0	0	293	2413
10^2–10^3	350 (97)	7 (2)	2 (< 1)	1 (< 1)	0	0	0	0	360	
10^3–10^4	760 (94)	36 (4)	7(< 1)	6 (< 1)	0	0	0	0	809	
10^4–10^5	391 (90)	22 (5)	15 (3)	2 (< 1)	4 (< 1)	0	0	0	434	
10^5–10^6	227 (80)	33 (12)	12 (4)	8 (3)	3 (1)	0	0	0	283	
10^6–10^7	108 (76)	15 (11)	10 (7)	7 (5)	1 (< 1)	1(< 1)	0	0	142	
10^7–10^8	39 (65)	6 (10)	6 (10)	8 (13)	0	0	1(2)	0	60	
$> 10^8$	21 (66)	4 (13)	3 (9)	4 (13)	0	0	0	0	32	

* Totals differ as in some instances only one test (coliforms or *E. coli*) was carried out.

Table 7. *Bacteriological criteria for goat's milk**

	Total bacterial count† per ml	Coliforms† absent in:
1. Raw		
(*a*) After cooling before delivery	⩽ 50000	0·001 ml (< 1000/ml)
(*b*) Direct from uninfected udder	⩽ 100	1 ml (< 1/ml)
Freshly packaged	⩽ 1000	0·1 ml (< 10 ml)
2. Pasteurized		
(*a*) After cooling before delivery	—	0·01 ml (< 100/ml)

Phosphatase test – ⩽ 10 μg p nitrophenol per ml of milk.

* Code of Practice on the Hygienic Control of Goats' Milk (1984) Department of Agriculture and Fisheries for Scotland.

† Incubated at 30 °C.

Survival and growth of pathogens in stored goat's milk

B. cereus, *Staph. aureus*, *Salm. typhimurium* and *Y. enterocolitica* incubated at 4, 22 and 30 °C survived quite well and at the higher temperatures multiplied by several logs in 24 h (Figs 1 and 2). *Cl. perfringens* increased only 10- to 100-fold in 24 h at 22 and 30 C. *C. jejuni* did not grow; numbers fell to below the threshold of detection at 72 h when held at 4, 22, 30 or 43 °C. At 4 °C all the test organisms decreased in numbers over the 72 h storage period but only *C. jejuni* became undetectable. *Y. enterocolitica* was still present but in reduced numbers after 1 week at 4 °C.

DISCUSSION

The problems associated with the consumption of raw cow's milk in the United Kingdom have been well documented (Galbraith, Forbes & Clifford, 1982) but reports of illness attributed to raw goat's milk are rare. The results of this survey indicate that goat's milk is a reasonably safe product. As 99% of the samples examined were raw, i.e. non-heat-treated, and the hygiene of production is far less well controlled than for cow's milk, the degree of bacterial contamination is low; 79% of samples gave counts of $< 10^5$ organisms per ml at 37 °C. There is no microbiological standard for goat's milk, but a code of practice has recently been produced in Scotland (Department of Agriculture and Fisheries for Scotland, 1984) which gives a suggested standard for both raw and pasteurized milk (Table 7). If this standard was applied to the samples examined in the P.H.L.S. survey, then 67% (1635/2429 samples) were satisfactory. They gave total bacterial counts of < 50000 per ml, with < 1000 coliforms per ml in compliance with the Scottish standard for raw milk sampled after cooling but before delivery; while 63·4% of samples gave counts of < 20000 per ml. This is equivalent to Band A (< 20000 per ml) of the Milk Marketing Board's standards for cow's milk delivered to dairies

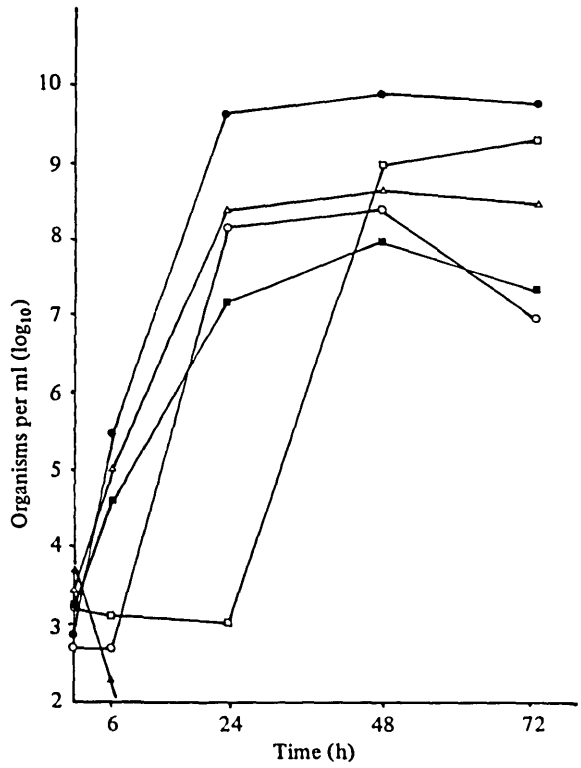

Fig. 1. Growth of food poisoning bacteria in goat's milk at 30 °C. ○, *B. cereus*, △, *Staph. aureus*, □, *Cl. perfringens*, ●, *Salm. typhimurium*, ▲, *C. jejuni*, ■, *Y. enterocolitica*.

for pasteurization and for which an additional payment is made. However, many of the survey samples were frozen and there may have been a reduction in numbers of bacteria as a result of the freezing process.

There is little published information on the microbiology of goat's milk although a number of small surveys that examined between 11 and 48 samples were carried out in various parts of England (Burton, 1980; Syska, 1980; Lewis, 1981; P.H.L.S. Maidstone, unpublished data). In most of these surveys the results were similar to those of the current survey – most samples gave total counts of $<10^5$ per ml. A somewhat larger survey in New South Wales (Jensen & Hughes, 1980) showed that goat's milk in Australia was of a poorer microbiological quality; a larger proportion of samples gave counts of $> 10^6$ per ml and high counts of *E. coli*. Moreover, *Salm. eimsbuettel* was isolated from one sample and *Y. enterocolitica* from 35 of 274 samples examined compared with no salmonella and only two isolates of *Y. enterocolitica* from our current survey of more than 2000 samples.

Freshly drawn milk from a healthy animal should be almost bacteria-free, but there are many means by which organisms can get into the milk: from the animal itself, from the environment and from the operatives carrying out the milking, packaging and distribution of the milk. The udder of the goat may become infected with many types of bacteria similar to those causing infections in cows' udders, e.g. staphylococci, streptococci, corynebacteria, coliforms and mycoplasmas.

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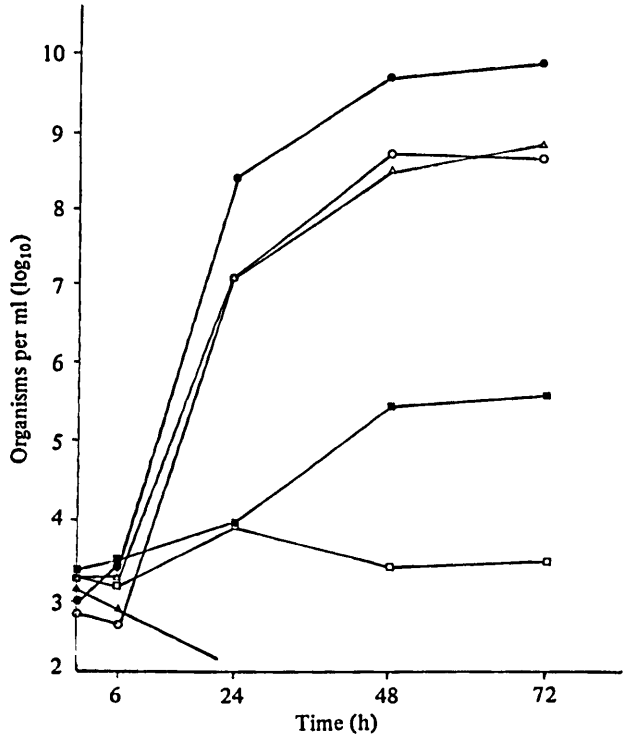

Fig. 2. Growth of food poisoning bacteria in goat's milk at 22 °C. ○, *B. cereus*, △, *Staph. aureus*, □, *Cl. perfringens*, ●, *Salm. typhimurium*, ▲, *C. jejuni*, ■, *Y. enterocolitica*.

Teats soiled with dung, mud and bedding materials, if not washed before milking, are a source of dirt and bacteria for the milk. At present most goats in this country are milked by hand. The most common utensils are plastic buckets and strainers, and unless thoroughly cleaned and disinfected these can contribute many organisms to the milk. Similarly, thorough cleaning of bulk milk tanks, bottles, carton-filling machines and returned empty milk bottles is also essential in order to avoid contamination.

Goats are browsers, not grazers like cattle, and thus may be less likely to pick up infection from pasture contaminated with faecal material. They also produce a dry faecal pellet unlike the large volume of moist dung produced by the cow. This also reduces the chance of contaminating the milk with faecal material and any pathogenic organisms it may contain.

The results of the survey indicate that any problems with goat's milk relate to poor hygiene during production rather than the transmission of organisms from the goat herself. The most common faults are high total bacterial counts rather than the presence of pathogens. However, our experiments showed that stored goat's milk provides a good medium for the growth of pathogens if it is not kept chilled (Figs 1 and 2). Freshly drawn milk exhibits some antibacterial activity (Auclair & Hirsch, 1953).

The growth in demand for goat's milk, and the fact that it is recommended as an alternative milk for infants who are allergic to cow's milk, suggest the need for

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controls in line with those for cow's milk. This raises a number of questions. (1) Is there a need for statutory tests for goat's milk? (2) Are the tests for cow's milk suitable? (3) Should the product be pasteurized? (4) If there are statutory tests should there also be microbiological specfications or guidelines for the product, and what should they be?

Statutory tests would be difficult to impose, as goat's milk production is still small relative to cow's milk. Similarly, compulsory pasteurization would be difficult to control, particularly as many producers have only a small number of animals and produce only small quantities of milk for distribution. Some of the statutory tests for cow's milk have been used in this survey. The methylene blue reduction test appears to be less reliable in goat's milk, but this could be due to the fact that much of the milk has been frozen before examination. The Brucella ring test is more difficult to read for goat's milk due to the small size of the fat globules. Since the main aim for goat's milk is for good general hygiene and keeping quality, a colony count and *E. coli* estimation may be the most useful tests to employ, with microbiological guidelines similar to those already put forward in Scotland. However, as no significant hazard has been attributed to the consumption of goat's milk, perhaps the best policy would be to keep a close watch on the development of the industry and to monitor samples regularly to look for adverse trends in microbiological quality. The greatest effect on microbiological quality is likely to be from improvement in the hygiene of milk production, distribution and storage.

Thanks are due to the many environmental health officers in various parts of England and Wales without whose co-operation in the collection of samples this survey would not have been possible. I am also indebted to Graham Watson of the Food Hygiene Laboratory, C.P.H.L., Colindale for writing and operating the computer program which facilitated analysis of the survey data, to Girish Munshi of the same laboratory for carrying out the growth experiments and to the director, Dr Richard Gilbert, for his support and encouragement.

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