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APPENDICES

Appendix A Microbiological analysis

1. Preparation of phosphate buffer solution

a) Stock Phosphate buffer and magnesium sulfate solution (44)

1 a) Phosphate buffer : Dissolve 34 g of potassium dihydrogen phosphate in 500 ml of distilled water, adjust to pH 7.2 with 1 N NaOH solution, and make up to 1 liter with distilled water. Sterilize at 121°C for 15 min, and store in refrigerator to prevent microbial growth.

2 a) Magnesium sulfate : Dissolve 50 g of $MgSO_4.7H_2O$ into 1 liter volumetric flask and add distilled water to make 1 liter of solution.

b) Buffer dilution water (44)

Add 1.25 ml of stock phosphate buffer solution and 5 ml of stock $MgSO_4.7H_2O$ solution to distilled water and make up to 1 liter. Pipette each 9 ml into a test-tube with screw cap. Sterilize at 121°c for 15 min.

2. Preparation of media

a) Plate count agar (PCA, Difco) (40,44)

Suspend 23.5 g of plate count agar in 1 liter of distilled water and heat to boiling to dissolve completely. Sterilize in autoclave at 121°C for 15 min.

The formula of ingredients per liter

Bacto tryptone	5 g
Bacto yeast extract	2.5 g
Bacto dextrose	1 g
Bacto agar	15 g

Final pH 7.0 ±0.2 at 25 °C

b) Violet red bile agar (VRB, Difco) (40, 44)

Suspend 41.5 g of violet red bile agar in1 liter of distilled water. Boil not more than 2 min. Do not autoclave.

The formula of ingredients per liter

Yeast extract	5 g
Peptone	7 g
Bile salt No.3	1.5 g
Lactose	10 g
Sodium chloride	5 g
Agar	15 g
Neutral red	0.03 g
Crystal Violet	0.002 g

c) Bacto Lactobacilli MRS agar (21)

Dissolve all the ingredients with the exception of glucose and agar by heating in the water bath, adjust pH to 6.2-6.6. Add agar and glucose, then sterilize at 121 °C for 15 min.

The formula of ingredients per liter

Bacto peptone	10 g

Bacto beef extract	10	g
Bacto yeast extract	5	g
Dextrose	20	g
Tween 80	1	g
Dipotassium hydrogen phosphate	2	g
Trisodium citrate	5	g
Magnesium sulphate	0.2	g
Manganese sulfate	0.05	g
Calcium carbonate	20	g
Bromocresol purple	0.04	g
Agar	15	g

Final pH 6.5 $\pm$ 0.2 at 25 °C

d) Spirit blue agar (Difco) (40)

Suspend 36 g of spirit blue agar in 1 liter distilled water and heat to boiling to dissolve completely. Sterilize at 121°c for 15 min.

The formula of ingredients per liter

Bacto tryptone	10	g
Bacto yeast extract	5	g
Bacto agar	20	g
Spirit blue	0.15	g

Final pH 6.8 $\pm$ 0.2 at 25 °C

3. Method of analysis

a) Standard plate count : Make and mix a series of milk with plate count agar in petridishes. Count the colonies after incubation at 32 ± 1°C for 48 ± 3 hours (40,44).

The dilutions used for raw milk were 10^{-4} and 10^{-5}, the dilutions used for pasteurized milk were 10^{-1} to 10^{-7}.

b) Psychrotrophic count : Make and mix a series of dilution of milk with plate count agar in petridishes. Count the colonies after incubation at 7 ± 1°C for 10 days (40, 44).

The dilutions used for raw milk were 10^{-2}, 10^{-3} and 10^{-4}; the dilutions used for pasteurized milk were 10^{0} to 10^{-7}

c) Coliform count : Make and mix a series of dilutions of milk with violet red bile agar in petridishes, overlay with agar. Count the colonies which are pink and bile precipitated after incubation at 32 ± 1°C for 24 ± 2 hours (40, 44).

The dilutions used for raw milk were 10^{-2}, 10^{-3} and 10^{-4}; the dilutions used for pasteurized milk were 10^{0} to 10^{-7}.

d) Lactic acid bacterial count : Make and mix a series of dilution of milk with Bacto Lactobacilli MRS agar in petridishes. Count the yellow colonies after incubation at 32°C for 18-24 hours or longer (21, 40).

The dilutions used for raw milk were 10^{-2}, 10^{-3} and 10^{-4} ; The dilutions used for pasteurized milk were 10^{0} to 10^{-7}.

Appendix B Chemical analysis

B 1. Titratable acidity

a) Preparation of reagents

1 a) Phenolphthalein indicator (41)

Dissolve 1 g of phenolphthalein in 110 ml ethyl alcohol (95% W/V) and add 0.1 M sodium hydroxide solution until the solution is faint pink. Add distilled water to a volume of 200 ml.

2 a) Standard 0.1 N sodium hydroxide (42)

Dissolve 4 g of sodium hydroxide in 1 liter boiled distilled water. Standardize the sodium hydroxide solution with pre-dried and pre-weighed potassium hydrogen phthalate (120°C, 2 hr.) as the method given below.

Dissolve the accurate weight of potassium hydrogen phthalate with 50 ml distilled water, titrate with about 40ml of the prepared sodium hydroxide solution, use phenolphthalein as an indicator. Calculate normality of standard sodium hydroxide solution by

$$N = g \times 1000/\text{ml sodium hydroxide} \times 204.229$$

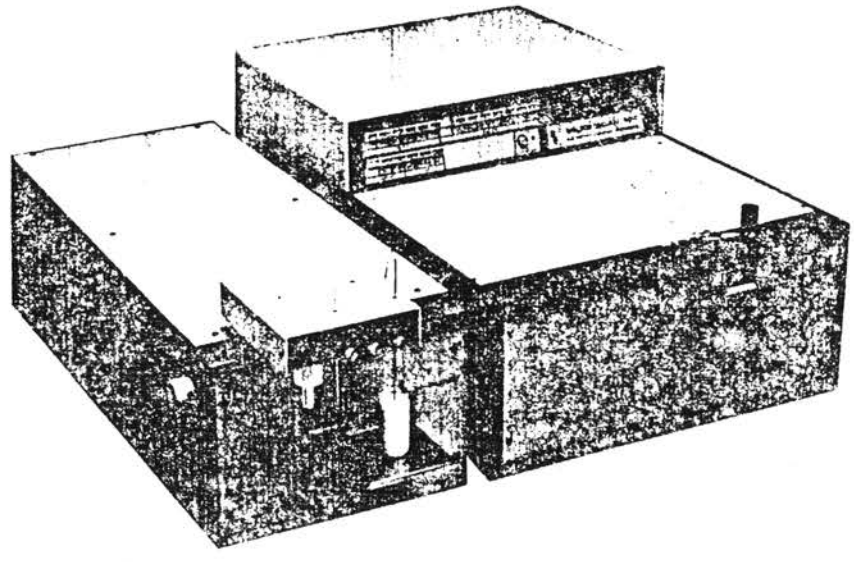
b) Method of analysis (41)

Pipette 10 ml of milk and 1 ml of phenolphthalein solution (as an indicator) into erlenmeyer flask. Titrate with standard 0.1 N sodium hydroxide solution until the solution is faint pink. Express titratable acidity in term of lactic acid (% w/v)

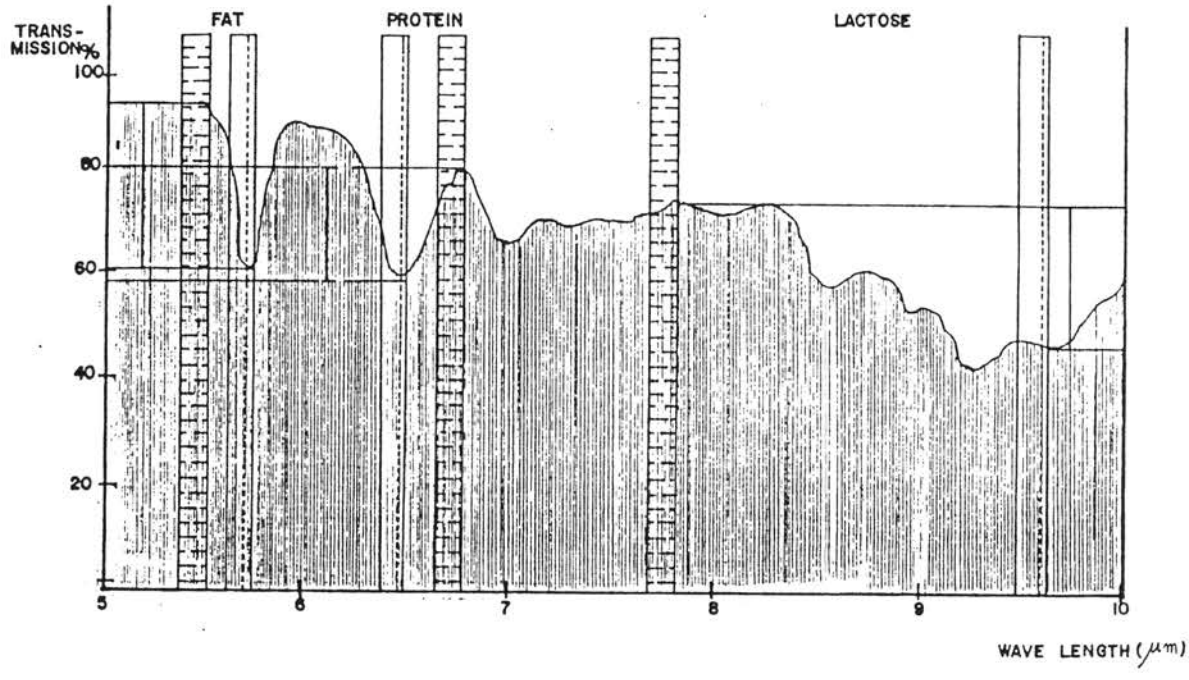
$$1 \text{ ml } 0.1 \text{ N NaOH} \equiv 0.009 \text{ g lactic acid}$$

B 2. Compositional analysis

a) Instrument : Analyse the chemical composition of milk by using Milko Scan 104 as shown in the figure below.



b) Principle method of analysis (43)



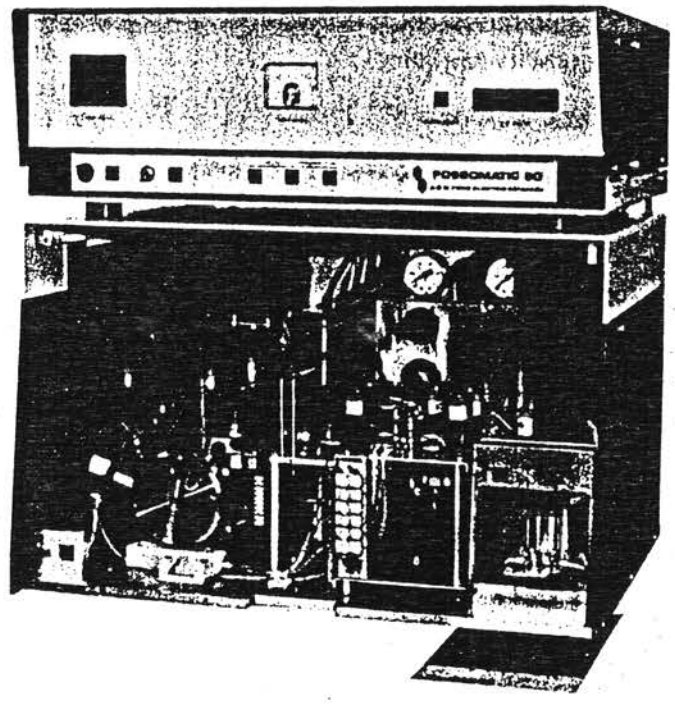
The principle measurement of Milko Scan 104 is similar to infrared absorption spectrophotometer; but this instrument used only one cuvette to measure the difference of transmission between the infrared absorption in the cuvette at different wavelengths, a sample absorption wavelength (BLANK) and a reference wavelength (LINE).

c. Method of analysis (43)

Turn on the instrument and warm up for 5 min. and set zero reading for the program of compositional analysis by using distilled water. Then, preheat milk in a water bath at 40°C and pump it through the instrument. The percentage of each item of compositional analysis will be recorded and read out from the recorder.

B 3. Somatic cell count

a) Instrument Count the somatic cells of milk by using Fossomatic90 as shown in the figure below.



b) reagents (22)

b 1) Stock solution :

b 1.1 1 0/00 Ethidium bromide: dissolve 1 g ethidium bromide in 1 liter distilled water. Store in a lightproof and airtight bottle no longer than 60 days.

b 1.2 1 0/0 Triton X-100: pipette 10 ml Triton X-100 in 1 liter distilled water, heat to 60°c. Store airtight for maximum 25 days.

b 1.3 Buffer solution : dissolve 51 g potassium hydrogen phthalate and 13.75 g potassium hydroxide in 10 liter distilled water and 150 ml Triton X-100 solution (b 1.2)

b 2) Working solution

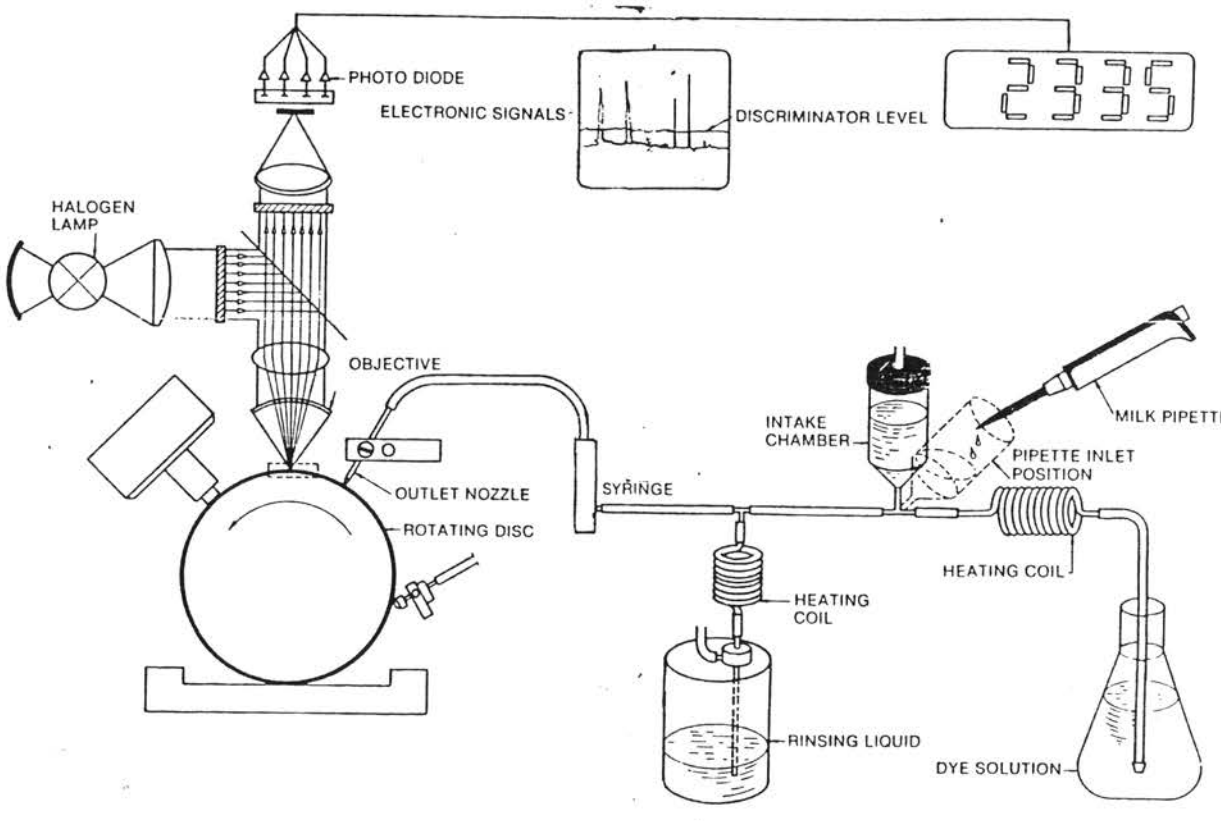
b 2.1 Dye solution : pipette 26 ml of 1 0/00 ethidium bromide solution (b 1.1) to 2.5 liter of buffer solution (b 1.3)

b 2.2 Rinsing liquid : pipette 10 ml 1 0/0 Triton X-100 (b 1.2) and 25 ml of a 25% ammonia solution to 10 liter distilled water.

c) Principle method of analysis

This instrument is based on fluoro-opto-electronic-cell-counting (FOECC). The process is done by pipetting 0.5 ml of milk sample into the intake chamber. Here the milk is mixed with 9.5 ml of warm dye solution which is automatically dispensed. After 10 seconds' reaction time, the suspension of stained cells is transferred to the microsyrings. The syrings will gradually dispense 40 µl of suspension as a thin film on to the edge of rotating disc which serves as the object plane for an automatic microscope; so the working factor is 500. Blue light from a halogen lamp illuminates the film, and as stained cells in the film pass the objective, they will emitted red light. A 4-channel high sensitivity detector will detect the light from each cell and display the signal on a monitor. The cells are counted, and the count displayed. A discriminator will cut off false pulses from

noise, bacteric and other foreign particles in the milk, ensuring that only cells are counted. All functions are microprocessor controlled. This includes automatic cleaning of the object plane and entire flow system between each sample.



d. Method of analysis

Turn on the pump and the instrument and heat up the milk sample to 40°C with water bath. Then, transfer 0.5 ml of milk sample to the intake chamber. Read the result which is displayed after 60 seconds. The unit is X 10^3 cells. Transfer another sample for reading after 40 seconds in order to give time for cleaning the chamber, flow system and objective plane automatically.

Appendix C Organoleptic analysis

1. Questionaire used for testing quality of milk

ใบประเมินผลทางประสาทสัมผัสตัวอย่างน้ำนม

ชื่อผู้ทดสอบ.....วันที่ทำการทดลอง.....

จากตัวอย่างน้ำนมต่อไปนี้ โปรดประเมินคุณภาพโดยให้คะแนนตามความเห็นและการยอมรับที่มีต่อตัวอย่างแต่ละตัวอย่างในเรื่องของสี กลิ่น รส mouthfeel และคุณภาพรวม โดยกำหนดให้คะแนนต่ำสุดซึ่งอยู่ในวงเล็บนั้นหมายถึง ไม่ชอบมากที่สุดหรือเลวที่สุด และคะแนนสูงสุดหมายถึง ชอบมากที่สุดหรือดีที่สุด ทั้งนี้โดยไม่ต้องเปรียบเทียบกันระหว่างตัวอย่างทั้งหมด

	หมายเลขตัวอย่าง									
สี (1-3)										
กลิ่น (1-7)										
รส (1-7)										
mouthfeel (1-3)										
คุณภาพรวม (1-9)										
การยอมรับตัวอย่าง										
✓ = ยอมรับ										
× = ไม่ยอมรับ										

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Appendix D Enzymatic analysis

D 1. Enzyme protease

a. Preparation of plates

Dissolve 100 ml of sterile plate count agar with 0.05 g thimerosol while the agar is heated. Cool down to 45 °C. Add 20 ml 25% sterile skim milk (121 °C, 10 min) and mix thoroughly. Pipette each 10 ml of the prepared agar in a sterile petridish, leave until the agar is set, then, press a hole of 3 mm. in diameter by using the tube joints with vacuum suction (7 holes/plate)

b. Method

Pipette 10 µl of milk into the hole of the plate prepared. Measure the size of the clear zone in millimeter by using divider after incubation at 37 ± 2 °C for 24 hrs. Negative and positive test have to be done by using sterile distilled water and enzyme protease solution.

D 2. Enzyme lipase

a. Preparation of plates

Dissolve 100 ml sterile spirit blue agar with 0.05g thimerosol while the agar is heated. Cool down to 50-55 °C, then, add 3 ml bacto lipase reagent (Difco) and mix thoroughly. Pipette each 10 ml of prepared agar in a sterile petridish, leave until the agar is set, then, press a hole of 3 mm. in diameter by using the tube suction with vacuum technique (7 holes/plate)

Formula of bacto lipase reagent: Dissolve 10 g gum acacia or 1 ml Tween 80 in 400 ml warm distilled water, add 100 ml cotton seed or olive oil and agitating vigorously to emulsify.

b. Method

Pipette 10 µl of milk into the hole of the plate prepared. Measure the size of the clear zone in millimeter using a divider after incubation at 37 ± 2°C for 24 hrs. Negative and positive test have to be done by using equal amount of distilled water and enzyme lipase solution.

Appendix E Sample of calculation

E 1. Sample of randomized complete block design (RCBD), missing value and comparable the difference of mean values using Duncan's multiple-range test (DMRT).

a. Purpose of analysis

To find out the difference of mean values of lactic acid bacterial counts in raw milk among various dairies.

b. Analysis of variance

dairy	log number of lactic acid bacteria (cfu/ml)			Total
	1	2	3	
A	4.477	5.265	4.638	14.380
B	3.889	3.863	3.602	11.354
C	4.204	4.477	4.833	13.514
D	a=4.373 *	4.813	4.255	13.440
E	4.724	4.623	b=4.585 *	13.933
	21.667	23.041	21.923	66.621

Note : a and b are missing values due to failure in the experiment, determined by calculation shown in the following.

c. Calculation of missing values (a and b)

$a = (\bar{X}i. + \bar{X}.j)/2$

$Xi.$ = mean value of treatment which has a missing value

$\bar{X}.j$ = mean value of block which has a missing value

$$\bar{X}i. = \frac{4.477+3.889+4.204+4.724}{4}$$

$$= 4.324$$

$$\bar{X}.j = \frac{4.813+4.255}{2}$$

$$= 4.534$$

$$a = \frac{4.324+4.534}{2}$$

$$= 4.429$$

$$b = \frac{rB+tT-G}{(r-1)(t-1)}$$

r = no.of block

t = no. of treatment

B = total value of the block which has a missing value

T = total value of the treatment which has a missing value

G = total value of the experimental units

$r = 3$, $t = 5$, $B = 17.328$, $T = 9.347$, $G = 62.092$

$$b = \frac{3 \times 17.328 + 5 \times 9.347 - 62.092}{2 \times 4}$$

$$b = 4.578$$

From the b value calculated, calculate back to a value using the missing value formula. Recalculate until the a or b value equal the former value.

From the calculation, we get the value of a and b as shown in the table below

a	b
4.429 →	4.578
4.373 ←	4.578
4.373 →	4.585
4.373 ←	4.585

So, the value of a is 4.373 and b is 4.585

d. Calculation sum of square (SS), mean square (MS) and F

1d)Treatment SS (SS_T) $= (\sum_{i=1}^{t} y^2 i./r) - (y^2../n)$

$= (14.380^2 + 11.354^2 + .. + 13.933^2)/3 - (66.621)^2/15$

$= 297.70 - 295.89$

$= 1.81$

2d)Block SS (SS_B) $= (\sum_{j=1}^{r} y^2.j/t) - (y^2../n)$

$= 21.667^2 + 23.041^2 + 21.923^2)$

$/5 - (66.621)^2/15$

$= 296.19 - 295.89$

$= 0.30$

3d) Total SS (SSy) $= \left(\sum_{i=1}^{t}\sum_{j=1}^{r} y^2ij\right)-(y^2../n)$

$= (4.477^2+3.889^2+..+4.585^2)$

$-(66.621)^2/15$

$= 298.48-295.89$

$= 2.59$

4d) Error SS $= SSy-SS_T-SS_B$

$= 2.59-1.81-0.30$

$= 0.48$

5d) Treatment MS $= SS_T/(t-1)$

$= 2.59/4$

$= 0.65$

6d) Block MS $= SS_B/(r-1)$

$= 0.30/2$

$= 0.15$

7d) Error MS $= SS_E/(t-1)(r-1)$

$= 0.48/(4X2-2)$

$= 0.08$

8d) F(Treatment) $= MS_T/MS_E$

$= 0.65/0.08$

$= 8.13$

9d) F(Block) $= MS_B/MS_E$

$= 0.15/0.08$

$= 1.88$

SOV	df	SS	MS	F_{cal}	$F_{0.05}$	$F_{0.01}$
Total	14	2.59	0.19			
Treatment	4	1.81	0.65	8.13^{*}	4.53	9.15
Block	2	0.30	0.15	1.88^{NS}	5.14	10.92
Error	$8-2^{+}=6$	0.48	0.08			

\+ = Minus degree of freedom from 2 missing values

SOV = source of variation

df = degree of freedom

SS = sum of square

MS = mean square

* = difference at 95% significant level

NS = difference is not significant

From the calculation, lactic acid bacteria in raw milk from each dairy is significantly different at 95% significant level, but there was no significantly difference between each sampling.

e. Difference of lactic acid bacteria among dairies

Using Duncan's multiple-range test (DMRT) to compare the difference of mean value of lactic acid bacteria among dairies.

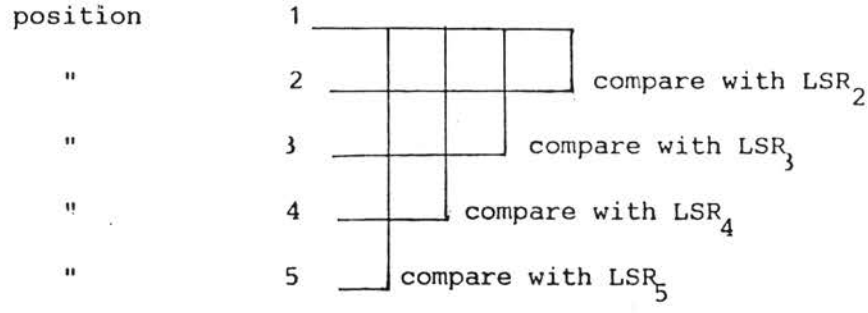
dairy	Mean value of lactic acid bacteria (cfu/ml)
A	4.79^{a}
B	3.78^{b}
C	4.50^{a}
D	4.48^{a}
E	4.64^{a}

For df = 6 at 95% significant level

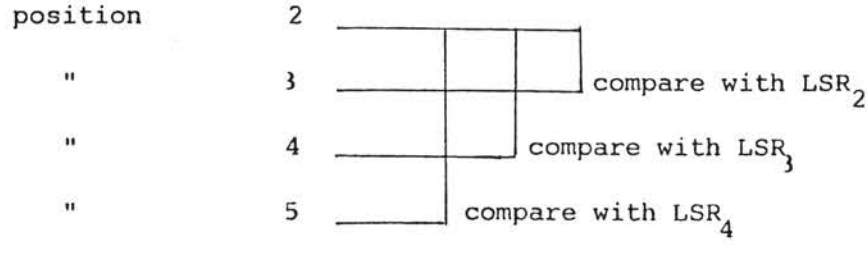
$$S\bar{x} = \sqrt{\frac{MS_E}{r}} = 0.1633$$

P	SSRp	LSRp
2	3.461	0.565
3	3.587	0.586
4	3.649	0.596
5	3.680	0.601

Comparing the least significant ranges (LSR) with the differences in ordered mean, the method is to compare the difference between the the first and the fifth mean values with LSR_5. If the difference is less than LSR_5, the difference of these two mean values is not significant; if it is more, the difference of these two mean values is significantly different at 95% level. Then, compare the first mean value with further ordered means as shown below until the difference is not significant.



Then, use the second mean instead of the first mean and compare like the first mean as shown below.



Then, use the third and the fourth mean to compare in the same manner.

The difference of the means by DMRT is presented by using alphabet. The values which have a same alphabet showed no difference between means. The significant level used is always at 95% level.

Compare the difference of means among dairies by drawing a line under any subset of adjecent means and writing the same alphabet over the mean values that are not significantly different.

	a	a	a	a	b
Mean value of lactic acid bacteria (cfu/ml)	4.79	4.64	4.50	4.48	3.78
Dairies	A	E	C	D	B

From the calculation, the mean values of lactic acid bacteria among dairies A,C,D and E arenot significantly different.

The mean value of lactic acid bacteria from dairy B is diffenent significantly from other dairies at 95% level.

E 2. Sample of 5X5 factorial with complete block design and comparable the difference of mean values using DMRT.

a. Purpose of analysis

To study the effect of storage temperature on shelf-life of pasteurized milk for all dairies.

b. Analysis of variance

Factor A = storage temperatures

A_1 = 5 °C

A_2 = 7°C

A_3 = 10°C

A_4 = 15 °C

A_5 = 20°C

Factor B = Dairies

B_1 = Dairy A

B_2 = Dairy B

B_3 = Dairy C

B_4 = Dairy D

B_5 = Dairy E

Table of data

Treatment	Block			Total
	1	2	3	
A_1B_1	20	30	23	73
A_1B_2	31	35	16	82
A_1B_3	16	15	10	41
A_1B_4	23	16	10	49
A_1B_5	27	31	16	74
A_2B_1	11	13	9	33
A_2B_2	11	9	11	31
A_2B_3	9	10	7	26
A_2B_4	9	7	7	23
A_2B_5	17	15	17	49
A_3B_1	8	10	7	25
A_3B_2	7	9	8	24
A_3B_3	7*	7	4	18
A_3B_4	6	4	3	13
A_3B_5	11*	11	11	33
A_4B_1	4	3	4	11
A_4B_2	3	4	4	11
A_4B_3	3	3	3	9
A_4B_4	3	3	3	9
A_4B_5	5	5	5	15
A_5B_1	2	2	3	7
A_5B_2	2	3	2	7
A_5B_3	2	2	2	6
A_5B_4	2	2	2	6
A_5B_5	3	3	3	9
Total	242	252	190	684

* Data calculated from the missing value formula. These missing data are due to the inadequate samples for analysis on the unacceptability of milk (see method of calculation in appendix E1)

Two-way classification table

FACTOR A / FACTOR B	5	7	10	15	20	Total A
A	73	82	41	49	74	319
B	33	31	26	23	49	162
C	25	24	18	13	33	113
D	11	11	9	9	15	55
E	7	7	6	6	9	35
Total B	149	155	100	100	180	684

c. Calculation of sum of square (SS), mean square (MS) and F

1c) correction factor (CF) $= \sum_{ijk}^{abr} y^2_{ijk}/abr$

$= \frac{684^2}{5 \times 5 \times 3}$

$= 6238.08$

2c) Total SS(SSy) $= \sum_{i=1}^{a} \sum_{j=1}^{b} \sum_{k=1}^{r} y^2_{ijk} - CF$

$= (20^2 + 30^2 + \ldots + 3^2) - 6238.08$

$= 10830 - 6238.08$

$= 4591.92$

3c) Block SS (SS_D) $= \sum_{k=1}^{r} y^2..k/ab - CF$

$= (242^2+252^2+190^2)/5x5$

-6238.08

$= 6326.72-6238.08$

$= 88.64$

4c) Treatment SS (SS_T) $= \sum_{i=1}^{a}\sum_{j=1}^{b} y^2ij./r-CF$

$= (73^2+82^2+...+9^2)/3-6238.08$

$= 10310-6238.08$

$= 4071.92$

5c) Factor A SS (SS_A) $= \sum_{i=1}^{a} y^2i../br-CF$

$= (319^2+162^2+...+35^2)/5x3$

-6238.08

$= 9668.27-6238.08$

$= 3430.19$

6c) Factor B SS (SS_B) $= \sum_{j=1}^{b} y^2.j./ar-CF$

$= (149^2+155^2+...+180^2)/$

$5x3-6238.08$

$= 6575.07-6238.08$

$= 336.99$

7c) Interaction SS (SS_{AB}) $= SS_T-SS_A-SS_B$

$= 4071.92-3430.19-336.99$

$= 304.74$

8c) Error SS $= SSy-SS_D-SS_T$

$= 4591.92-88.64-4071.92$

$= 431.36$

9c) Block MS (MS_D) $= \frac{SS_D}{r-1}$

$= \frac{88.64}{2}$

$= 44.32$

10c) Factor A MS (MS_A) $= \frac{SS_A}{a-1}$

$= \frac{3430.19}{4}$

$= 857.55$

11c) Factor B MS (MS_B) $= \frac{SS_B}{b-1}$

$= 336.99/4$

$= 84.25$

12c) Interaction MS (MS_{AB}) $= \frac{SS_{AB}}{(a-1)(b-1)}$

$= 304.74/4x4$

$= 19.05$

13c) Error MS (MS_E) $= \frac{SS_E}{(ab-1)(r-1)}$

$= 431.36/46$

$= 9.38$

14c) F(A) $= MS_A/MS_E$

$= 857.55/9.38$

$= 91.42$

15c) F(B) $= MS_B/MS_E$

$= 84.25/9.38$

$= 8.98$

16c) F(interaction) $= MS_{AB}/MS_E$

$= 19.05/9.38$

$= 2.03$

17c) F(block) $= MS_D/MS_E$

$= 44.32/9.38$

$= 4.72$

Analysis of variance table

SOV	df	SS	MS	F_{cal}	$F_{0.05}$	$F_{0.01}$
Total	74	4591.92	62.05			
Block	2	88.64	44.32	4.72^{*}	3.20	5.10
A	4	3430.19	857.55	91.42^{**}	2.57	3.76
B	4	336.99	84.25	8.98^{**}	2.57	3.76
AxB	16	304.74	19.05	2.03^{*}	1.87	2.42
Error	$48-2^{+}$	431.36	9.38			

+ = Minus degree of freedom from two missing values

SOV = Source of variation

df = degree of freedom

SS = Sum of square

MS = Mean square

* = difference at 95% significant level

** = difference at 99% significant level

From the calculation, there is a significant difference of interaction between storage temperatures and dairies; so, it is necessary to explain each effect on shelf-life of pasteurized

milk. In this experiment, DMRT is used to compare the difference of shelf-life of pasteurized milk at various storage temperatures and among dairies.

d. Differences between mean value using DMRT (see appendis E1)

Table of mean values (average from 3 replications)

Storage temp.(°C)	DAIRIES				
	A	B	C	D	E
5	24.3	27.3	13.7	16.3	24.7
7	11.0	10.3	8.7	7.7	16.3
10	8.3	8.0	6.0	4.3	11.0
15	3.7	3.7	3.0	3.0	5.0
20	2.3	2.3	2.0	2.0	3.0

$$S\bar{x}_{AxB} = \sqrt{\frac{MS_E}{r}}$$

$$= \sqrt{\frac{9.38}{3}}$$

$$= 1.7682$$

For df =46, at 95% significant level

P	SSR	LSR
2	2.8493	5.04
3	2.916	5.16
4	3.0933	5.47
5	3.1626	5.59

Compare the difference of means by drawing a line under any subset of adjecent means and writing the same alphabet over the means that are not significantly different.

Compare the mean values at various storage temperatures

	a	b	bc	c	d
Dairy A	24.3	11.0	8.3	3.7	2.3
	a	b	bc	c	d
Dairy B	27.3	10.3	8.0	3.7	2.3
	a	b	bc	bc	c
Dairy C	13.7	8.7	5.8	3.0	2.0
	a	b	bc	bc	c
Dairy D	16.3	7.7	4.3	3.0	2.0
	a	b	c	d	d
Dairy E	24.7	16.3	11.0	5.0	3.0

From the calculation, there is a significantly different of shelf life at various storage temperatures for all dairies at 95% level.

Compare the mean values among dairies

	a	a	a	b	b
At 5°C	27.3	24.3	24.3	16.3	13.7
	a	b	b	b	b
At 7°C	16.3	11.0	10.3	8.7	7.7
	a	ab	ab	ab	b
At 10°C	11.0	8.3	8.0	5.8	4.3
	a	a	a	a	a
At 15°C	5	3.7	3.7	3.0	3.0
	a	a	a	a	a
At 20°C	3	2.3	2.3	2.0	2.0

From the calculation, five dairies were divided into three groups for all ranges of storage temperatures between 5 and 20°C as shown below.

Storage temp (°C)	DAIRY A	DAIRY B	DAIRY C	DAIRY D	DAIRY E
5	24.3^{a}	27.3^{a}	13.7^{b}	16.3^{b}	24.7^{a}
7	11.0^{b}	10.3^{b}	8.7^{b}	7.7^{b}	16.3^{a}
10	8.3^{ab}	8.0^{ab}	5.8^{ab}	4.3^{b}	11.0^{a}
15	3.7^{a}	3.7^{a}	3.0^{a}	3.0^{a}	5.0^{a}
20	2.3^{a}	2.3^{a}	2.0^{a}	2.0^{a}	3.0^{a}

DMRT (comparison of 5 dairies at the same storage temperature)

When divided these 5 dairies into 3 groups, it is a little difference of shelf-life between dairy C and D at 10°C-storage temperature, but it is suitable to group these two dairies together because they use the same packing material. Besides, the difference of shelf-life is less than at 5°C-storage temperatures if dairy A, B and C are grouped together and the packaging material they used is different.

E3. The linear regression (parameters, correlation coefficient and the significance of linearity.

a. Purpose of analysis

To estimate the parameter of linear regression between standard plate count and psychrotrophic count, the correlation coefficient and the significance of the linearity.

b. Method Data used are from Fig 4.6 P54

Sample No.	Log no. of standard plate count/ml x	Log no.of psychrotrophic count/ml y
1	3.477	3.301
2	2.903	1.477
3	5.58	5.255
	.	.
	.	.
	.	.
	.	.
	.	.
	.	.
	.	.
	.	.
n(302)	.....	.....

For the regression line $\bar{Y}x = a+bx$

$$b = \frac{n\sum_{i=1}^{n} XiYi - (\sum_{i=1}^{n} Xi)(\sum_{i=1}^{n} Yi)}{n\sum_{i=1}^{n} X^2i - (\sum_{i=1}^{n} Xi)^2} \qquad (46, 47, 48)$$

$$a = \bar{y}-b\bar{x}$$

From the calculation, $b = 1.08$

$a = -1.00$

So, the linear regression is $y = -1.00+1.08x$

For the correlation coefficient

$$r = \frac{n\sum_{i=1}^{n} XiYi - (\sum_{i=1}^{n} Xi)(\sum_{i=1}^{n} Yi)}{\sqrt{[n\sum_{i=1}^{n} X^2i - (\sum_{i=1}^{n} Xi)^2][n\sum_{i=1}^{n} Y^2i-(\sum_{i=1}^{n} Yi)^2]}} \qquad (46,47,48)$$

From the calculation, $r = 0.94$

Test of significance of linear correlation

$$Z = \frac{\sqrt{n-3}}{2} \ln \frac{(1+r)}{1-r} \qquad (46)$$

Data from fig 4.6, n = 302

$$Z = \frac{\sqrt{302-3}}{2} \ln \left[\frac{1+0.94}{1-0.94}\right]$$

$$Z = 21.57$$

Compare Z value with the critical values of t Distribution at df = ∞. If the calculated Z value is greater than the critical value. We accept the hypothsis of linearity.

α	t
0.025	1.960
0.005	2.576

From the calculation, the linear correlation coefficient is significant at 99% level.

So, it can be concluded that the relationship between log no.of standard plate count and psychrotrophic count is a linear whose the equations are:

log P/ml = -1.00+1.08 log SPC/ml (r=0.90, P<0.01)

where SPC = standard plate count

P = psychrotrophic count

E4. The multiple linear regression (parameters, correlation coefficient and the significance of linearity.

a. Purpose of analysis

To estimate the parameters of multiple linear regression between standard plate count, psychrotrophic count and coliform count, the multiple linear correlation coefficient and the significance of the linearity.

b. Method (Data used are from fig 4.6 and 4.7)

Sample No.	log no.of standard plate count/ml (X_1)	log no.of psychrotrophic count/ml (X_2)	log no.of coliform count/ml (X_3)
1	3.477	3.301	1.158
2	2.903	1.477	2.601
3	5.58	5.255	2.114
	.	.	.
	.	.	.
	.	.	.
	.	.	.
	.	.	.
	.	.	.
n = 95	.....	.....	.....

For the multiple regression line

$$X_1 = a+b_2X_2+b_3X_3$$

Calculate the parameter using the equation below (47, 48)

$$\Sigma(x_2^2)b_2+\Sigma(x_2x_3)b_3 = \Sigma(x_1x_2)$$

$$\Sigma(x_2x_3)b_2+\Sigma(x_3^2)b_3 = \Sigma(x_1x_3)$$

$$a = \bar{X}_1 - b_2\bar{X}_2 - b_3\bar{X}_3$$

when $$\Sigma(x_1x_2) = \Sigma X_1X_2 - n\bar{X}_1\bar{X}_2$$

$$\Sigma(x_1^2) = \Sigma X_1^2 - n(\bar{X}_1)^2$$

From the calculation,

$$b_3 = 0.1941$$

$$b_2 = 0.7027$$

$$a = 1.9791$$

So, the multiple linear regression is

$$X_1 = 1.9791+0.7027\ X_2+0.1941\ X_3$$

For the correlation coefficient,

$$R^2 = \frac{\text{Sum of square due to regression}}{\text{total sum of squares}} \quad (47,48)$$

$$= \frac{SSR}{\Sigma X_1^2}$$

where SSR $= b_2\Sigma X_1X_2 + b_3\Sigma X_1X_3$ (47, 48)

From the calculation, $R^2 = 0.9405$

$R = 0.97$

Test of significance of R^2 by using F-statistic as follows:

$$F = \frac{SSR/k}{SSE/n-k-1}$$

where SSE $= X_1^2 - SSR$

$$F = \frac{200.44}{0.268}$$

$$= 751.23^{**}$$

$F_{0.01,\ 2,\ 95} = 4.83$

F-value from the calculation is greater than the tabular F-value, with k and n-k-1 degrees of freedom. R^2 is said to be significant, indicating that some protion of the variability in X_1 is explained by the independent variables (X_2, X_3) through the regression equation.

We can conclude the relationship between standard plate count, psychrotrophic count and coliform count as the equation shown below.

$$\log \text{SPC/ml} = 1.9791 + 0.7027 \log \text{P/ml} + 0.1941 \log \text{C/ml}$$

where SPC = standard plate count

P = psychrotrophic count

C = coliform count

Points for the distribution of F [5% (light type) and 1% (bold face type)]

f_2	f_1 Degrees of freedom (for greater mean square)																						f_2
	1	2	3	4	5	6	7	8	9	10	11	12	14	16	20	24	30	40	50	75	100	200	500	∞	
1	161 4,052	200 4,999	216 5,403	225 5,625	230 5,764	234 5,859	237 5,928	239 5,981	241 6,022	242 6,056	243 6,082	244 6,106	245 6,142	246 6,169	248 6,208	249 6,234	250 6,261	251 6,286	252 6,302	253 6,323	253 6,334	254 6,352	254 6,361	254 6,366	1
2	18.51 98.49	19.00 99.00	19.16 99.17	19.25 99.25	19.30 99.30	19.33 99.33	19.36 99.36	19.37 99.37	19.38 99.39	19.39 99.40	19.40 99.41	19.41 99.42	19.42 99.43	19.43 99.44	19.44 99.45	19.45 99.46	19.46 99.47	19.47 99.48	19.47 99.48	19.48 99.49	19.49 99.49	19.49 99.49	19.50 99.50	19.50 99.50	2
3	10.13 34.12	9.55 30.82	9.28 29.46	9.12 28.71	9.01 28.24	8.94 27.91	8.89 27.67	8.84 27.49	8.81 27.34	8.78 27.23	8.76 27.13	8.74 27.05	8.71 26.92	8.69 26.83	8.66 26.69	8.64 26.60	8.62 26.50	8.60 26.41	8.58 26.35	8.57 26.27	8.56 26.23	8.54 26.18	8.54 26.14	8.53 26.12	3
4	7.71 21.20	6.94 18.00	6.59 16.69	6.39 15.98	6.26 15.52	6.16 15.21	6.09 14.98	6.04 14.80	6.00 14.66	5.96 14.54	5.93 14.45	5.91 14.37	5.87 14.24	5.84 14.15	5.80 14.02	5.77 13.93	5.74 13.83	5.71 13.74	5.70 13.69	5.68 13.61	5.66 13.57	5.65 13.52	5.64 13.48	5.63 13.46	4
5	6.61 16.26	5.79 13.27	5.41 12.06	5.19 11.39	5.05 10.97	4.95 10.67	4.88 10.45	4.82 10.29	4.78 10.16	4.74 10.05	4.70 9.96	4.68 9.89	4.64 9.77	4.60 9.68	4.56 9.55	4.53 9.47	4.50 9.38	4.46 9.29	4.44 9.24	4.42 9.17	4.40 9.13	4.38 9.07	4.37 9.04	4.36 9.02	5
6	5.99 13.74	5.14 10.92	4.76 9.78	4.53 9.15	4.39 8.76	4.28 8.47	4.21 8.26	4.15 8.10	4.10 7.98	4.06 7.87	4.03 7.79	4.00 7.72	3.96 7.60	3.92 7.52	3.87 7.39	3.84 7.31	3.81 7.23	3.77 7.14	3.75 7.09	3.72 7.02	3.71 6.99	3.69 6.94	3.68 6.90	3.67 6.88	6
7	5.59 12.25	4.74 9.55	4.35 8.45	4.12 7.85	3.97 7.46	3.87 7.19	3.79 7.00	3.73 6.84	3.68 6.71	3.63 6.62	3.60 6.54	3.57 6.47	3.52 6.35	3.49 6.27	3.44 6.15	3.41 6.07	3.38 5.98	3.34 5.90	3.32 5.85	3.29 5.78	3.28 5.75	3.25 5.70	3.24 5.67	3.23 5.65	7
8	5.32 11.26	4.46 8.65	4.07 7.59	3.84 7.01	3.69 6.63	3.58 6.37	3.50 6.19	3.44 6.03	3.39 5.91	3.34 5.82	3.31 5.74	3.28 5.67	3.23 5.56	3.20 5.48	3.15 5.36	3.12 5.28	3.08 5.20	3.05 5.11	3.03 5.06	3.00 5.00	2.98 4.96	2.96 4.91	2.94 4.88	2.93 4.86	8
9	5.12 10.56	4.26 8.02	3.86 6.99	3.63 6.42	3.48 6.06	3.37 5.80	3.29 5.62	3.23 5.47	3.18 5.35	3.13 5.26	3.10 5.18	3.07 5.11	3.02 5.00	2.98 4.92	2.93 4.80	2.90 4.73	2.86 4.64	2.82 4.56	2.80 4.51	2.77 4.45	2.76 4.41	2.73 4.36	2.72 4.33	2.71 4.31	9
10	4.96 10.04	4.10 7.56	3.71 6.55	3.48 5.99	3.33 5.64	3.22 5.39	3.14 5.21	3.07 5.06	3.02 4.95	2.97 4.85	2.94 4.78	2.91 4.71	2.86 4.60	2.82 4.52	2.77 4.41	2.74 4.33	2.70 4.25	2.67 4.17	2.64 4.12	2.61 4.05	2.59 4.01	2.56 3.96	2.55 3.93	2.54 3.91	10
11	4.84 9.65	3.98 7.20	3.59 6.22	3.36 5.67	3.20 5.32	3.09 5.07	3.01 4.88	2.95 4.74	2.90 4.63	2.86 4.54	2.82 4.46	2.79 4.40	2.74 4.29	2.70 4.21	2.65 4.10	2.61 4.02	2.57 3.94	2.53 3.86	2.50 3.80	2.47 3.74	2.45 3.70	2.42 3.66	2.41 3.62	2.40 3.60	11
12	4.75 9.33	3.88 6.93	3.49 5.95	3.26 5.41	3.11 5.06	3.00 4.82	2.92 4.65	2.85 4.50	2.80 4.39	2.76 4.30	2.72 4.22	2.69 4.16	2.64 4.05	2.60 3.98	2.54 3.86	2.50 3.78	2.46 3.70	2.42 3.61	2.40 3.56	2.36 3.49	2.35 3.46	2.32 3.41	2.31 3.38	2.30 3.36	12
13	4.67 9.07	3.80 6.70	3.41 5.74	3.18 5.20	3.02 4.86	2.92 4.62	2.84 4.44	2.77 4.30	2.72 4.19	2.67 4.10	2.63 4.02	2.60 3.96	2.55 3.85	2.51 3.78	2.46 3.67	2.42 3.59	2.38 3.51	2.34 3.42	2.32 3.37	2.28 3.30	2.26 3.27	2.24 3.21	2.22 3.18	2.21 3.16	13
14	4.60 8.86	3.74 6.51	3.34 5.56	3.11 5.03	2.96 4.69	2.85 4.46	2.77 4.28	2.70 4.14	2.65 4.03	2.60 3.94	2.56 3.86	2.53 3.80	2.48 3.70	2.44 3.62	2.39 3.51	2.35 3.43	2.31 3.34	2.27 3.26	2.24 3.21	2.21 3.14	2.19 3.11	2.16 3.06	2.14 3.02	2.13 3.00	14
15	4.54 8.68	3.68 6.36	3.29 5.42	3.06 4.89	2.90 4.56	2.79 4.32	2.70 4.14	2.64 4.00	2.59 3.89	2.55 3.80	2.51 3.73	2.48 3.67	2.43 3.56	2.39 3.48	2.33 3.36	2.29 3.29	2.25 3.20	2.21 3.12	2.18 3.07	2.15 3.00	2.12 2.97	2.10 2.92	2.08 2.89	2.07 2.87	15
16	4.49 8.53	3.63 6.23	3.24 5.29	3.01 4.77	2.85 4.44	2.74 4.20	2.66 4.03	2.59 3.89	2.54 3.78	2.49 3.69	2.45 3.61	2.42 3.55	2.37 3.45	2.33 3.37	2.28 3.25	2.24 3.18	2.20 3.10	2.16 3.01	2.13 2.96	2.09 2.98	2.07 2.86	2.04 2.80	2.02 2.77	2.01 2.75	16
17	4.45 8.40	3.59 6.11	3.20 5.18	2.96 4.67	2.81 4.34	2.70 4.10	2.62 3.93	2.55 3.79	2.50 3.68	2.45 3.59	2.41 3.52	2.38 3.45	2.33 3.35	2.29 3.27	2.23 3.16	2.19 3.08	2.15 3.00	2.11 2.92	2.08 2.86	2.04 2.79	2.02 2.76	1.99 2.70	1.97 2.67	1.96 2.65	17
18	4.41 8.28	3.55 6.01	3.16 5.09	2.93 4.58	2.77 4.25	2.66 4.01	2.58 3.85	2.51 3.71	2.46 3.60	2.41 3.51	2.37 3.44	2.34 3.37	2.29 3.27	2.25 3.19	2.19 3.07	2.15 3.00	2.11 2.91	2.07 2.83	2.04 2.78	2.00 2.71	1.98 2.68	1.95 2.62	1.93 2.59	1.92 2.57	18
19	4.38 8.18	3.52 5.93	3.13 5.01	2.90 4.50	2.74 4.17	2.63 3.94	2.55 3.77	2.48 3.63	2.43 3.52	2.38 3.43	2.34 3.36	2.31 3.30	2.26 3.19	2.21 3.12	2.15 3.00	2.11 2.92	2.07 2.84	2.02 2.76	2.00 2.70	1.96 2.63	1.94 2.60	1.91 2.54	1.90 2.51	1.88 2.49	19
20	4.35 8.10	3.49 5.85	3.10 4.94	2.87 4.43	2.71 4.10	2.60 3.87	2.52 3.71	2.45 3.56	2.40 3.45	2.35 3.37	2.31 3.30	2.28 3.23	2.23 3.13	2.18 3.05	2.12 2.94	2.08 2.86	2.04 2.77	1.99 2.69	1.96 2.63	1.92 2.56	1.90 2.53	1.87 2.47	1.85 2.44	1.84 2.42	20
21	4.32 8.02	3.47 5.78	3.07 4.87	2.84 4.37	2.68 4.04	2.57 3.81	2.49 3.65	2.42 3.51	2.37 3.40	2.32 3.31	2.28 3.24	2.25 3.17	2.20 3.07	2.15 2.99	2.09 2.88	2.05 2.80	2.00 2.72	1.96 2.63	1.93 2.58	1.89 2.51	1.87 2.47	1.84 2.42	1.82 2.38	1.81 2.36	21
22	4.30 7.94	3.44 5.72	3.05 4.82	2.82 4.31	2.66 3.99	2.55 3.76	2.47 3.59	2.40 3.45	2.35 3.35	2.30 3.26	2.26 3.18	2.23 3.12	2.18 3.02	2.13 2.94	2.07 2.83	2.03 2.75	1.98 2.67	1.93 2.58	1.91 2.53	1.87 2.46	1.84 2.42	1.81 2.37	1.80 2.33	1.78 2.31	22
23	4.28 7.88	3.42 5.66	3.03 4.76	2.80 4.26	2.64 3.94	2.53 3.71	2.45 3.54	2.38 3.41	2.32 3.30	2.28 3.21	2.24 3.14	2.20 3.07	2.14 2.97	2.10 2.89	2.04 2.78	2.00 2.70	1.96 2.62	1.91 2.53	1.88 2.48	1.84 2.41	1.82 2.37	1.79 2.32	1.77 2.28	1.76 2.26	23
24	4.26 7.82	3.40 5.61	3.01 4.72	2.78 4.22	2.62 3.90	2.51 3.67	2.43 3.50	2.36 3.36	2.30 3.25	2.26 3.17	2.22 3.09	2.18 3.03	2.13 2.93	2.09 2.85	2.02 2.74	1.98 2.66	1.94 2.58	1.89 2.49	1.86 2.44	1.82 2.36	1.80 2.33	1.76 2.27	1.74 2.23	1.73 2.21	24
25	4.24 7.77	3.38 5.57	2.99 4.68	2.76 4.18	2.60 3.86	2.49 3.63	2.41 3.46	2.34 3.32	2.28 3.21	2.24 3.13	2.20 3.05	2.16 2.99	2.11 2.89	2.06 2.81	2.00 2.70	1.96 2.62	1.92 2.54	1.87 2.45	1.84 2.40	1.80 2.32	1.77 2.29	1.74 2.23	1.72 2.19	1.71 2.17	25
26	4.22 7.72	3.37 5.53	2.98 4.64	2.74 4.14	2.59 3.82	2.47 3.59	2.39 3.42	2.32 3.29	2.27 3.17	2.22 3.09	2.18 3.02	2.15 2.96	2.10 2.86	2.05 2.77	1.99 2.66	1.95 2.58	1.90 2.50	1.85 2.41	1.82 2.36	1.78 2.28	1.76 2.25	1.72 2.19	1.70 2.15	1.69 2.13	26
27	4.21 7.68	3.35 5.49	2.96 4.60	2.73 4.11	2.57 3.79	2.46 3.56	2.37 3.39	2.30 3.26	2.25 3.14	2.20 3.06	2.16 2.98	2.13 2.93	2.08 2.83	2.03 2.74	1.97 2.63	1.93 2.55	1.88 2.47	1.84 2.38	1.80 2.33	1.76 2.25	1.74 2.21	1.71 2.16	1.68 2.12	1.67 2.10	27
28	4.20 7.64	3.34 5.45	2.95 4.57	2.71 4.07	2.56 3.76	2.44 3.53	2.36 3.36	2.29 3.23	2.24 3.11	2.19 3.03	2.15 2.95	2.12 2.90	2.06 2.80	2.02 2.71	1.96 2.60	1.91 2.52	1.87 2.44	1.81 2.35	1.78 2.30	1.75 2.22	1.72 2.18	1.69 2.13	1.67 2.09	1.65 2.06	28
29	4.18 7.60	3.33 5.42	2.93 4.54	2.70 4.04	2.54 3.73	2.43 3.50	2.35 3.33	2.28 3.20	2.22 3.08	2.18 3.00	2.14 2.92	2.10 2.87	2.05 2.77	2.00 2.68	1.94 2.57	1.90 2.49	1.85 2.41	1.80 2.32	1.77 2.27	1.73 2.19	1.71 2.15	1.68 2.10	1.65 2.06	1.64 2.03	29
30	4.17 7.56	3.32 5.39	2.92 4.51	2.69 4.02	2.53 3.70	2.42 3.47	2.34 3.30	2.27 3.17	2.21 3.06	2.16 2.98	2.12 2.90	2.09 2.84	2.04 2.74	1.99 2.66	1.93 2.55	1.89 2.47	1.84 2.38	1.79 2.29	1.76 2.24	1.72 2.16	1.69 2.13	1.66 2.07	1.64 2.03	1.62 2.01	30
32	4.15 7.50	3.30 5.34	2.90 4.46	2.67 3.97	2.51 3.66	2.40 3.42	2.32 3.25	2.25 3.12	2.19 3.01	2.14 2.94	2.10 2.86	2.07 2.80	2.02 2.70	1.97 2.62	1.91 2.51	1.86 2.42	1.82 2.34	1.76 2.25	1.74 2.20	1.69 2.12	1.67 2.08	1.64 2.02	1.61 1.98	1.59 1.96	32
34	4.13 7.44	3.28 5.29	2.88 4.42	2.65 3.93	2.49 3.61	2.38 3.38	2.30 3.21	2.23 3.08	2.17 2.97	2.12 2.89	2.08 2.82	2.05 2.76	2.00 2.66	1.95 2.58	1.89 2.47	1.84 2.38	1.80 2.30	1.74 2.21	1.71 2.15	1.67 2.08	1.64 2.04	1.61 1.98	1.59 1.94	1.57 1.91	34
36	4.11 7.39	3.26 5.25	2.86 4.38	2.63 3.89	2.48 3.58	2.36 3.35	2.28 3.18	2.21 3.04	2.15 2.94	2.10 2.86	2.06 2.78	2.03 2.72	1.98 2.62	1.93 2.54	1.87 2.43	1.82 2.35	1.78 2.26	1.72 2.17	1.69 2.12	1.65 2.04	1.62 2.00	1.59 1.94	1.56 1.90	1.55 1.87	36
38	4.10 7.35	3.25 5.21	2.85 4.34	2.62 3.86	2.46 3.54	2.35 3.32	2.26 3.15	2.19 3.02	2.14 2.91	2.09 2.82	2.05 2.75	2.02 2.69	1.96 2.59	1.92 2.51	1.85 2.40	1.80 2.32	1.76 2.22	1.71 2.14	1.67 2.08	1.63 2.00	1.60 1.97	1.57 1.90	1.54 1.86	1.53 1.84	38
40	4.08 7.31	3.23 5.18	2.84 4.31	2.61 3.83	2.45 3.51	2.34 3.29	2.25 3.12	2.18 2.99	2.12 2.88	2.07 2.80	2.04 2.73	2.00 2.66	1.95 2.56	1.90 2.49	1.84 2.37	1.79 2.29	1.74 2.20	1.69 2.11	1.66 2.05	1.61 1.97	1.59 1.94	1.55 1.88	1.53 1.84	1.51 1.81	40
42	4.07 7.27	3.22 5.16	2.83 4.29	2.59 3.80	2.44 3.49	2.32 3.26	2.24 3.10	2.17 2.96	2.11 2.86	2.06 2.77	2.02 2.70	1.99 2.64	1.94 2.54	1.89 2.46	1.82 2.35	1.78 2.26	1.73 2.17	1.68 2.08	1.64 2.02	1.60 1.94	1.57 1.91	1.54 1.85	1.51 1.80	1.49 1.78	42
44	4.06 7.24	3.21 5.12	2.82 4.26	2.58 3.78	2.43 3.46	2.31 3.24	2.23 3.07	2.16 2.94	2.10 2.84	2.05 2.75	2.01 2.68	1.98 2.62	1.92 2.52	1.88 2.44	1.81 2.32	1.76 2.24	1.72 2.15	1.66 2.06	1.63 2.00	1.58 1.92	1.56 1.88	1.52 1.82	1.50 1.78	1.48 1.75	44
46	4.05 7.21	3.20 5.10	2.81 4.24	2.57 3.76	2.42 3.44	2.30 3.22	2.22 3.05	2.14 2.92	2.09 2.82	2.04 2.73	2.00 2.66	1.97 2.60	1.91 2.50	1.87 2.42	1.80 2.30	1.75 2.22	1.71 2.13	1.65 2.04	1.62 1.98	1.57 1.90	1.54 1.86	1.51 1.80	1.48 1.76	1.46 1.72	46
48	4.04 7.19	3.19 6.08	2.80 4.22	2.56 3.74	2.41 3.42	2.30 3.20	2.21 3.04	2.14 2.90	2.08 2.80	2.03 2.71	1.99 2.64	1.96 2.58	1.90 2.48	1.86 2.40	1.79 2.28	1.74 2.20	1.70 2.11	1.64 2.02	1.61 1.96	1.56 1.88	1.53 1.84	1.50 1.78	1.47 1.73	1.45 1.70	48
50	4.03 7.17	3.18 6.06	2.79 4.20	2.56 3.72	2.40 3.41	2.29 3.18	2.20 3.02	2.13 2.88	2.07 2.78	2.02 2.70	1.98 2.62	1.95 2.56	1.90 2.46	1.85 2.39	1.78 2.26	1.74 2.18	1.69 2.10	1.63 2.00	1.60 1.94	1.55 1.86	1.52 1.82	1.48 1.76	1.46 1.71	1.44 1.68	50
55	4.02 7.12	3.17 6.01	2.78 4.16	2.54 3.68	2.38 3.37	2.27 3.15	2.18 2.98	2.11 2.85	2.05 2.75	2.00 2.66	1.97 2.59	1.93 2.53	1.88 2.43	1.83 2.35	1.76 2.23	1.72 2.15	1.67 2.06	1.61 1.98	1.58 1.90	1.52 1.82	1.50 1.78	1.46 1.71	1.43 1.66	1.41 1.64	55
60	4.00 7.08	3.15 4.98	2.76 4.13	2.52 3.65	2.37 3.34	2.25 3.12	2.17 2.95	2.10 2.82	2.04 2.72	1.99 2.63	1.95 2.56	1.92 2.50	1.86 2.40	1.81 2.32	1.75 2.20	1.70 2.12	1.65 2.03	1.59 1.93	1.56 1.87	1.50 1.79	1.48 1.74	1.44 1.68	1.41 1.63	1.39 1.60	60
65	3.99 7.04	3.14 4.95	2.75 4.10	2.51 3.62	2.36 3.31	2.24 3.09	2.15 2.93	2.08 2.79	2.02 2.70	1.98 2.61	1.94 2.54	1.90 2.47	1.85 2.37	1.80 2.30	1.73 2.18	1.68 2.09	1.63 2.00	1.57 1.90	1.54 1.84	1.49 1.76	1.46 1.71	1.42 1.64	1.39 1.60	1.37 1.56	65
70	3.98 7.01	3.13 4.92	2.74 4.08	2.50 3.60	2.35 3.29	2.23 3.07	2.14 2.91	2.07 2.77	2.01 2.67	1.97 2.59	1.93 2.51	1.89 2.45	1.84 2.35	1.79 2.28	1.72 2.15	1.67 2.07	1.62 1.98	1.56 1.88	1.53 1.82	1.47 1.74	1.45 1.69	1.40 1.62	1.37 1.56	1.35 1.53	70
80	3.96 6.96	3.11 4.88	2.72 4.04	2.48 3.56	2.33 3.25	2.21 3.04	2.12 2.87	2.05 2.74	1.99 2.64	1.95 2.55	1.91 2.48	1.88 2.41	1.82 2.32	1.77 2.24	1.70 2.11	1.65 2.03	1.60 1.94	1.54 1.84	1.51 1.78	1.45 1.70	1.42 1.65	1.38 1.57	1.35 1.52	1.32 1.49	80
100	3.94 6.90	3.09 4.82	2.70 3.98	2.46 3.51	2.30 3.20	2.19 2.99	2.10 2.82	2.03 2.69	1.97 2.59	1.92 2.51	1.88 2.43	1.85 2.36	1.79 2.26	1.75 2.19	1.68 2.06	1.63 1.98	1.57 1.89	1.51 1.79	1.48 1.73	1.42 1.64	1.39 1.59	1.34 1.51	1.30 1.46	1.28 1.43	100
125	3.92 6.84	3.07 4.78	2.68 3.94	2.44 3.47	2.29 3.17	2.17 2.95	2.08 2.79	2.01 2.65	1.95 2.56	1.90 2.47	1.86 2.40	1.83 2.33	1.77 2.23	1.72 2.15	1.65 2.03	1.60 1.94	1.55 1.85	1.49 1.75	1.45 1.68	1.39 1.59	1.36 1.54	1.31 1.46	1.27 1.40	1.25 1.37	125
150	3.91 6.81	3.06 4.75	2.67 3.91	2.43 3.44	2.27 3.14	2.16 2.92	2.07 2.76	2.00 2.62	1.94 2.53	1.89 2.44	1.85 2.37	1.82 2.30	1.76 2.20	1.71 2.12	1.64 2.00	1.59 1.91	1.54 1.83	1.47 1.72	1.44 1.66	1.37 1.56	1.34 1.51	1.29 1.43	1.25 1.37	1.22 1.33	150
200	3.89 6.76	3.04 4.71	2.65 3.88	2.41 3.41	2.26 3.11	2.14 2.90	2.05 2.73	1.98 2.60	1.92 2.50	1.87 2.41	1.83 2.34	1.80 2.28	1.74 2.17	1.69 2.09	1.62 1.97	1.57 1.88	1.52 1.79	1.45 1.69	1.42 1.62	1.35 1.53	1.32 1.48	1.26 1.39	1.22 1.33	1.19 1.28	200
400	3.86 6.70	3.02 4.66	2.62 3.83	2.39 3.36	2.23 3.06	2.12 2.85	2.03 2.69	1.96 2.55	1.90 2.46	1.85 2.37	1.81 2.29	1.78 2.23	1.72 2.12	1.67 2.04	1.60 1.92	1.54 1.84	1.49 1.74	1.42 1.64	1.38 1.57	1.32 1.47	1.28 1.42	1.22 1.32	1.16 1.24	1.13 1.19	400
1000	3.85 6.66	3.00 4.62	2.61 3.80	2.38 3.34	2.22 3.04	2.10 2.82	2.02 2.66	1.95 2.53	1.89 2.43	1.84 2.34	1.80 2.26	1.76 2.20	1.70 2.09	1.65 2.01	1.58 1.89	1.53 1.81	1.47 1.71	1.41 1.61	1.36 1.54	1.30 1.44	1.26 1.38	1.19 1.28	1.13 1.19	1.08 1.11	1000
∞	3.84 6.64	2.99 4.60	2.60 3.78	2.37 3.32	2.21 3.02	2.09 2.80	2.01 2.64	1.94 2.51	1.88 2.41	1.83 2.32	1.79 2.24	1.75 2.18	1.69 2.07	1.64 1.99	1.57 1.87	1.52 1.79	1.46 1.69	1.40 1.59	1.35 1.52	1.28 1.41	1.24 1.36	1.17 1.25	1.11 1.15	1.00 1.00	∞

Significant studentized ranges for 5% and 1% level new multiple range test

Error df	Protection level	p = number of means for range being tested													
		2	3	4	5	6	7	8	9	10	12	14	16	18	20
1	.05	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0
	.01	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0	90.0
2	.05	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09
	.01	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
3	.05	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50	4.50
	.01	8.26	8.5	8.6	8.7	8.8	8.9	8.9	9.0	9.0	9.0	9.1	9.2	9.3	9.3
4	.05	3.93	4.01	4.02	4.02	4.02	4.02	4.02	4.02	4.02	4.02	4.02	4.02	4.02	4.02
	.01	6.51	6.8	6.9	7.0	7.1	7.1	7.2	7.2	7.3	7.3	7.4	7.4	7.5	7.5
5	.05	3.64	3.74	3.79	3.83	3.83	3.83	3.83	3.83	3.83	3.83	3.83	3.83	3.83	3.83
	.01	5.70	5.96	6.11	6.18	6.26	6.33	6.40	6.44	6.5	6.6	6.6	6.7	6.7	6.8
6	.05	3.46	3.58	3.64	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68	3.68
	.01	5.24	5.51	5.65	5.73	5.81	5.88	5.95	6.00	6.0	6.1	6.2	6.2	6.3	6.3
7	.05	3.35	3.47	3.54	3.58	3.60	3.61	3.61	3.61	3.61	3.61	3.61	3.61	3.61	3.61
	.01	4.95	5.22	5.37	5.45	5.53	5.61	5.69	5.73	5.8	5.8	5.9	5.9	6.0	6.0
8	.05	3.26	3.39	3.47	3.52	3.55	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56	3.56
	.01	4.74	5.00	5.14	5.23	5.32	5.40	5.47	5.51	5.5	5.6	5.7	5.7	5.8	5.8
9	.05	3.20	3.34	3.41	3.47	3.50	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52	3.52
	.01	4.60	4.86	4.99	5.08	5.17	5.25	5.32	5.36	5.4	5.5	5.5	5.6	5.7	5.7
10	.05	3.15	3.30	3.37	3.43	3.46	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.47	3.48
	.01	4.48	4.73	4.88	4.96	5.06	5.13	5.20	5.24	5.28	5.36	5.42	5.48	5.54	5.55
11	.05	3.11	3.27	3.35	3.39	3.43	3.44	3.45	3.46	4.46	3.46	3.46	3.46	3.47	3.48
	.01	4.39	4.63	4.77	4.86	4.94	5.01	5.06	5.12	5.15	5.24	5.28	5.34	5.38	5.39
12	.05	3.08	3.23	3.33	3.36	3.40	3.42	3.44	3.44	3.46	3.46	3.46	3.46	3.47	3.48
	.01	4.32	4.55	4.68	4.76	4.81	4.92	4.96	5.02	5.07	5.13	5.17	5.22	5.24	5.26
13	.05	3.06	3.21	3.30	3.35	3.38	3.41	3.42	3.44	3.45	3.45	3.46	3.46	3.47	3.47
	.01	4.26	4.48	4.62	4.69	4.74	4.84	4.88	4.94	4.98	5.04	5.08	5.13	5.14	5.15
14	.05	3.03	3.18	3.27	3.33	3.37	3.39	3.41	3.42	3.44	3.45	3.46	3.46	3.47	3.47
	.01	4.21	4.42	4.55	4.63	4.70	4.78	4.83	3.87	4.91	4.96	5.00	5.04	5.06	5.07
15	.05	3.01	3.16	3.25	3.31	3.36	3.38	3.40	3.42	3.43	3.44	3.45	3.46	3.47	3.47
	.01	4.17	4.37	4.50	4.58	4.64	4.72	4.77	4.81	4.84	4.90	4.94	4.97	4.99	5.00
16	.05	3.00	3.15	3.23	3.30	3.34	3.37	3.39	3.41	3.43	3.44	3.45	3.46	3.47	3.47
	.01	4.13	4.34	4.45	4.54	4.60	4.67	4.72	4.76	4.79	4.84	4.88	4.91	4.93	4.94
17	.05	2.98	3.13	3.22	3.28	3.33	3.36	3.38	3.40	3.42	3.44	3.45	3.46	3.47	3.47
	.01	4.10	4.30	4.41	4.50	4.56	4.63	4.68	4.72	4.75	4.80	4.83	4.86	4.88	4.89
18	.05	2.97	3.12	3.21	3.27	3.32	3.35	3.37	3.39	3.41	3.43	3.45	3.46	3.47	3.47
	.01	4.07	4.27	4.38	4.46	4.53	4.59	4.64	4.68	4.71	4.76	4.79	4.82	4.84	4.85
19	.05	2.96	3.11	3.19	3.26	3.31	3.35	3.37	3.39	3.41	3.43	3.44	3.46	3.47	3.47
	.01	4.05	4.24	4.35	4.43	4.50	4.56	4.61	4.64	4.67	4.72	4.76	4.79	4.81	4.82
20	.05	2.95	3.10	3.18	3.25	3.30	3.34	3.36	3.38	3.40	3.43	3.44	3.46	3.46	3.47
	.01	4.02	4.22	4.33	4.40	4.47	4.53	4.58	4.61	4.65	4.69	4.73	3.76	4.78	4.79
22	.05	2.93	3.08	3.17	3.24	3.29	3.32	3.35	3.37	3.39	3.42	3.44	3.45	3.46	3.47
	.01	3.99	4.17	4.28	4.36	4.42	4.48	4.53	4.57	4.60	4.65	4.68	4.71	4.74	4.75
24	.05	2.92	3.07	3.15	3.22	3.28	3.31	3.34	3.37	3.38	3.41	3.44	3.45	3.46	3.47
[illegible]	.01	3.96	4.14	4.24	4.33	4.39	4.44	4.49	4.53	4.57	4.62	4.64	4.67	4.70	4.72
26	.05	2.91	3.06	3.14	3.21	3.27	3.30	3.34	3.36	3.38	3.41	3.43	3.45	3.46	3.47
	.01	3.93	4.11	4.21	4.30	4.36	4.41	4.46	4.50	4.53	4.58	4.62	4.65	4.67	4.69
28	.05	2.90	3.04	3.13	3.20	3.26	3.30	3.33	3.35	3.37	3.40	3.43	3.45	3.46	3.47
	.01	3.91	4.08	4.18	4.28	4.34	4.39	4.43	4.47	4.51	4.56	4.60	4.62	4.65	4.67
30	.05	2.89	3.04	3.12	3.20	3.25	3.29	3.32	3.35	3.37	3.40	3.43	3.44	3.46	3.47
	.01	3.89	4.06	4.16	4.22	4.32	4.36	4.41	4.45	4.48	4.54	4.58	4.61	4.63	4.65
40	.05	2.86	3.01	3.10	3.17	3.22	3.27	3.30	3.33	3.35	3.39	3.42	3.44	3.46	3.47
	.01	3.82	3.99	4.10	4.17	4.21	4.30	4.34	4.37	4.41	4.46	4.51	4.54	4.57	4.59
60	.05	2.83	2.98	3.08	3.14	3.20	3.24	3.28	3.31	3.33	3.37	3.40	3.43	3.45	3.47
	.01	3.76	3.92	4.03	4.12	4.17	4.23	4.27	4.31	4.34	4.39	4.44	4.47	4.50	4.53
100	.05	2.80	2.95	3.05	3.12	3.18	3.22	3.26	3.29	3.32	3.36	3.40	3.42	3.45	3.47
	.01	3.71	3.86	3.98	4.06	4.11	4.17	4.21	4.25	4.29	4.35	4.38	4.42	4.45	4.48
∞	.05	2.77	2.92	3.02	3.09	3.15	3.19	3.23	3.25	3.29	3.34	3.38	3.41	3.44	3.47
	.01	3.64	3.80	3.90	3.98	4.04	4.09	4.14	4.17	4.20	4.26	4.31	4.34	4.38	4.41

Distribution of t probability

n	.9	.8	.7	.6	.5	.4	.3	.2	.1	.05	.02	.01	.001
1	.158	.325	.510	.727	1.000	1.376	1.963	3.078	6.314	12.706	31.821	63.657	636.619
2	.142	.289	.445	.617	.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	31.598
3	.137	.277	.424	.584	.765	.978	1.250	1.638	2.353	3.182	4.541	5.841	12.924
4	.134	.271	.414	.569	.741	.941	1.190	1.533	2.132	2.776	3.747	4.604	8.610
5	.132	.267	.408	.559	.727	.920	1.156	1.476	2.015	2.571	3.365	4.032	6.869
6	.131	.265	.404	.553	.718	.906	1.134	1.440	1.943	2.447	3.143	3.707	5.959
7	.130	.263	.402	.549	.711	.896	1.119	1.415	1.895	2.365	2.998	3.499	5.408
8	.130	.262	.399	.546	.706	.889	1.108	1.397	1.860	2.306	2.896	3.355	5.041
9	.129	.261	.398	.543	.703	.883	1.100	1.383	1.833	2.262	2.821	3.250	4.781
10	.129	.260	.397	.542	.700	.879	1.093	1.372	1.812	2.228	2.764	3.169	4.587
11	.129	.260	.396	.540	.697	.876	1.088	1.363	1.796	2.201	2.718	3.106	4.437
12	.128	.259	.395	.539	.695	.873	1.083	1.356	1.782	2.179	2.681	3.055	4.318
13	.128	.259	.394	.538	.694	.870	1.079	1.350	1.771	2.160	2.650	3.012	4.221
14	.128	.258	.393	.537	.692	.868	1.076	1.345	1.761	2.145	2.624	2.977	4.140
15	.128	.258	.393	.536	.691	.866	1.074	1.341	1.753	2.131	2.602	2.947	4.073
16	.128	.258	.392	.535	.690	.865	1.071	1.337	1.746	2.120	2.583	2.921	4.015
17	.128	.257	.392	.534	.689	.863	1.069	1.333	1.740	2.110	2.567	2.898	3.965
18	.127	.257	.392	.534	.688	.862	1.067	1.330	1.734	2.101	2.552	2.878	3.922
19	.127	.257	.391	.533	.688	.861	1.066	1.328	1.729	2.093	2.539	2.861	3.883
20	.127	.257	.391	.533	.687	.860	1.064	1.325	1.725	2.086	2.528	2.845	3.850
21	.127	.257	.391	.532	.686	.859	1.063	1.323	1.721	2.080	2.518	2.831	3.819
22	.127	.256	.390	.532	.686	.858	1.061	1.321	1.717	2.074	2.508	2.819	3.792
23	.127	.256	.390	.532	.685	.858	1.060	1.319	1.714	2.069	2.500	2.807	3.767
24	.127	.256	.390	.531	.685	.857	1.059	1.318	1.711	2.064	2.492	2.797	3.745
25	.127	.256	.390	.531	.684	.856	1.058	1.316	1.708	2.060	2.485	2.787	3.725
26	.127	.256	.390	.531	.684	.856	1.058	1.315	1.706	2.056	2.479	2.779	3.707
27	.127	.256	.389	.531	.684	.855	1.057	1.314	1.703	2.052	2.473	2.771	3.690
28	.127	.256	.389	.530	.683	.855	1.056	1.313	1.701	2.048	2.467	2.763	3.674
29	.127	.256	.389	.530	.683	.854	1.055	1.311	1.699	2.045	2.462	2.756	3.659
30	.127	.256	.389	.530	.683	.854	1.055	1.310	1.697	2.042	2.457	2.750	3.646
40	.126	.255	.388	.529	.681	.851	1.050	1.303	1.684	2.021	2.423	2.704	3.551
60	.126	.254	.387	.527	.679	.848	1.046	1.296	1.671	2.000	2.390	2.660	3.460
120	.126	.254	.386	.526	.677	.845	1.041	1.289	1.658	1.980	2.358	2.617	3.373
∞	.126	.253	.385	.524	.674	.842	1.036	1.282	1.645	1.960	2.326	2.576	3.291

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