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Microbiological Quality of Ready-to-eat Food Products in Southern Taiwan

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ABSTRACT

This study was to assess the microbiological quality of commercial ready-to-eat (RTE) food products sold in southern Taiwan. A total of 126 RTE food samples, including staple, meat, seafood, and vegetarian food products, were purchased from traditional markets, supermarkets, and warehouse stores. These foods were kept at refrigerator, room temperature, or hot stored at the time of sale. Aerobic plate count (APC), coliform, *Escherichia coli*, and *Staphylococcus aureus* were evaluated. APC in excess of 5 log CFU/g was obtained in traditional markets (27 samples), supermarkets (20 samples), and warehouse stores (15 samples). Seafood products were the most contaminated compared to staple products, meat products, or vegetarian foods. The highest incidence of APC greater than 5 log CFU/g was detected from food products stored at room temperature. Refrigerator stored food products were the second incidence, followed by hot kept food products. No significant differences were found for coliform and *E. coli* among the various markets or food types ($p > 0.05$). RTE food products sold in the traditional market, supermarkets, and warehouse stores contaminated with *S. aureus* were 19.0%, 12.7%, and 9.5%, respectively. The percentage of samples over-contaminated with *S. aureus* was 15.9% (seafood), 9.5% (staple and meat products), and 6.3% (vegetarian food products). RTE food products stored at room temperature had the highest contamination of *S. aureus*, followed by refrigerator and hot stored food products ($p < 0.05$).

Key words: ready-to-eat foods, microbiological quality

INTRODUCTION

Ready-to-eat (RTE) food products have become more popular in Taiwan. RTE foods are prepared and sold in public markets, i.e. supermarkets, warehouse stores, and traditional markets, and they provide consumer for immediate consumption or for consumption with simple processing or preparation. However, RTE products possess a managerial challenge to the food safety authority for continuous surveillance of the quality and preparation of the foods[1,2,3]. Between 1981 and 2001, 1279 of the 1376 food poisoning cases reported in Taiwan were associated with bacterial contamination. The incidence of food poisoning with regard to locations of occurrence was in the order of home (714 cases, 31%), commercial places (651 cases, 28.4%), and educational institutes (440 cases, 19.2%)[4].

Microbiological studies carried out on street-vending in several developing countries have reported high bacterial counts in foods[5,6]. Previous studies found that street-vended foods in Johannesburg contained *Bacillus cereus* (22%), *Clostridium perfringnes* (16%), *Salmonella* spp. (2%), and *E. coli* (2%) in South Africa[7]. Keneko *et al.*[8] found that mixed vegetable salad was the most heavily contaminated food item among the tested RTE food products supplied by retail shops and food factories, but no *Listeria monocytogenes* was detected. One of the tested Japanese warm food products was found positive for *S. aureus*. Study on 13 towns of Africa, the United States, and Asian Pacific revealed that 12.47 to 82.9% of street-vended ice products and juices were unsatisfactory, whereas the microbiological qualities of 11.3 to 92% sandwiches were under the acceptable standards[9]. Investigation of microbiological quality of cooked rice served in restaurants and take-away premises in England illustrated that 1% of those products was below the hygiene standards. Compared to point-of-sale cooked rice, precooked rice was significantly more contaminated with *Bacillus* spp., *Bacillus cereus,* and *E. coli*[10].

The present study examined the microbiological qualities of 4 types of RTE food products (i.e. staple, meat, seafood, and vegetarian food products) sold in traditional markets, supermarkets and warehouse stores, and were kept at refrigerator, room and hot storage temperatures.

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MATERIALS AND METHODS

I. *Collection of Samples*

RTE food products were periodically purchased from traditional markets, supermarkets, and warehouse stores in Tainan, Taiwan within the period of November 2002 to November 2003. A total of 126 samples were collected, including 44, 40 and 42 items, from traditional markets, supermarkets and warehouse stores, respectively. Among the collected samples, 33 staple products, 30 meat products, 33 seafood products, and 30 vegetarian food products were included. These food products were kept at refrigerator (5~7°C), room temperature (22~28°C), or hot storage (60~65°C) at the time of sale.

II. *Preparation of Samples*

Twenty five gram of each sample was homogenized with 225 mL of 0.1% sterilized peptone water using a Stomacher (model 400, Seward Medical, London, UK) for 2 min. Serial 10 fold dilutions were prepared with 0.1 sterile peptone water.

III. *Microbiological Analyses*

(I) *Aerobic Plate Count (APC)*

The aerobic viable cells were counted on Plate Count Agar (PCA, Difco Co., Detroit, MI, USA) with an automatic spiral plater (Spiral system, Model DU2, Cincinnati, OH, USA) and incubated at 37°C for 48 hr.

(II) *E. coli and Coliform*

Chromocult Coliform Agar (CCA, Merck Co., Darmstsdt, Germany) was used for the enumeration of *E. coli* and coliform following manufacturer's instructions[(11)]. Dilutions were plated and incubated at 37ºC for 24~48 hr. Purplish red colonies were identified as coliform whereas blue colonies were identified as *E. coli*.

(III) *S. aureus*

Sample dilutions were plated on Baird-Parker agar (Oxoid, Hampshire, England) with egg yolk emulsion (50 mL/L) and K_2TeO_3 solution (10 mg/L). The plated agar was incubated at 37°C for 48 hr for colony formation. Typical black colonies were further analyzed with Staphaurex rapid test kit (Welcome Diagnostics, England) for confirmation[(12)].

(IV) *Data Analysis*

Each test was performed in triplicate. All data were analyzed using Microsoft Excel program. Chi-square (χ^2) tests were used to determine the existence of statistically significant differences amongst the frequencies of samples for unsatisfactory microbiological quality between various type of foods from different markets and at vending temperatures. $p < 0.05$ was considered statistically significance.

RESULTS

I. *Microbial Count in RTE Foods*

The count of microbial population is presented in Table 1. APC of food samples obtained from traditional markets, supermarkets, and warehouse stores, was 3~9, 1~8 and 1~7 log CFU/g, respectively, where as coliforms were present in amount of 2~7, 1~7 and 2~5 log CFU/g of food samples. The detection rates were 68, 40 and 45% for food products sold at traditional markets, supermarkets, and warehouse stores, respectively. *E. coli* was detected in 5% (2~3 log CFU/g) and 7% (2~4 log CFU/g) of the food samples obtained from supermarkets and warehouse stores, respectively, whereas *E. coli* was not detected in the food sold at traditional markets. But the highest prevalence of *S. aureus* was found in food products distributed by traditional markets (54%), followed by food sold at supermarkets (40%) and warehouse stores (28%). *S. aureus* counts were in the range of 2~7 log CFU/g for food products from traditional markets, 1~6 log CFU/g for food items obtained from supermarkets, and 2~4 log CFU/g for food products sold at ware-

Table 1. Microbial count of aerobic plate count, coliform, *E. coli* and *S. aureus* in RTE food products sold at different markets

Place	No. of samples	Range of microbial count, log CFU/g (% positive)			
		APC	Coliform	*E. coli*	*S. aureus*
Traditional market	44	3.10~9.29 (100)	2.00~7.28 (68)	ND[a]	2.00~7.48 (54)
Supermarket	40	1.97~8.65 (100)	1.30~7.54 (40)	2.00~3.27 (5)	1.60~6.05 (40)
Warehouse stores	42	1.55~7.74 (100)	2.00~5.60 (45)	2.00~4.20 (7)	2.00~4.11 (28)

[a]Not detected.

Table 2. Microbial count of aerobic plate count, coliform, *E. coli* and *S. aureus* in various RTE food products

Major ingredients	No. of samples	Range of microbial count log CFU/g (% positive)			
		APC	Coliform	*E. coli*	*S. aureus*
Staple food	33	2.30~5.45 (100)	2.00~4.72 (52)	ND[a]	2.00~5.15 (36)
Meat food	30	1.55~7.61 (100)	2.00~5.75 (52)	2 (3)	1.60~5.81 (43)
Seafood	33	3.39~7.28 (100)	1.30~7.28 (51)	2.00~4.20 (12)	2.00~7.48 (61)
Vegetarian food	30	2.22~9.29 (100)	2.00~5.74 (37)	ND	2.00~6.05 (27)

[a]Not detected.

Table 3. Microbial count of aerobic plate count, coliform, *E. coli* and *S. aureus* in different selling temperatures of RTE food products

Selling temperature	No. of samples	Range of microbial count log CFU/g (% positive)			
		APC	Coliform	*E. coli*	*S. aureus*
Refrigerator[a]	40	2.14~7.74 (40)	2.00~5.60 (25)	3.28~4.20 (3)	2.60~7.48 (17)
Room[b]	44	1.97~8.65 (44)	1.33~7.27 (29)	2.00 (2)	2.00~6.05 (24)
Hot[c]	42	1.55~9.28 (42)	2.00~5.75 (11)	ND[d]	2.00~4.23 (11)

[a]The range of low temperature was 5~7°C.
[b]The range of room temperature was 22~28°C.
[c]The range of hot temperature was 60~65°C.
[d]Not detected.

house stores. Table 2 shows the range of microbial counts of hygiene indicator bacteria and pathogenic indicator *S. aureus* from different types of RTE food products. APC was 2~5 log CFU/g for staple products, 1~7 log CFU/g for meat products, 3~7 log CFU/g for seafood products, and 2~9 log CFU/g for vegetarian food products. Among the samples, detection rate over 50% of the staple, meat and seafood food contained 2~4, 2~5, 1~7 log CFU/g, respectively, contamination with coliform. The detection rate of coliform in vegetarian food products was 37%, lower than other food types, and ranged from 2~5 log CFU/g. *E. coli* was detected in meat and seafood products. Seafood products represented the higher rate of occurrence for *E. coli* (12%). About 61% of the seafood products were tested positive for *S. aureus* ranging from 2~7 log CFU/g, representing the most contaminated food category. Forty three, 36 and 27% of meat, staple and vegetarian food products were contaminated with *S. aureus*, respectively. Table 3 shows detection rate of the hygiene indicators and the pathogenic indicator (*S. aureus*) with respect to the storage/selling temperatures. Total aerobic plate counts were 2~7, 1~8 and 1~9 log CFU/g, for RTE food products kept at refrigerator, room and hot temperatures, respectively. Food products that were kept at room temperature had the highest incidence of coliform contamination (29%), followed by refrigerator (25%) and hot (11%) storage temperatures. Hot kept food products were free from the *E. coli* contamination. Food products that were stored at refrigerator and room temperatures had detection rates of 3 and 2% for *E. coli*, respectively. Similar results were obtained for *S. aureus*.

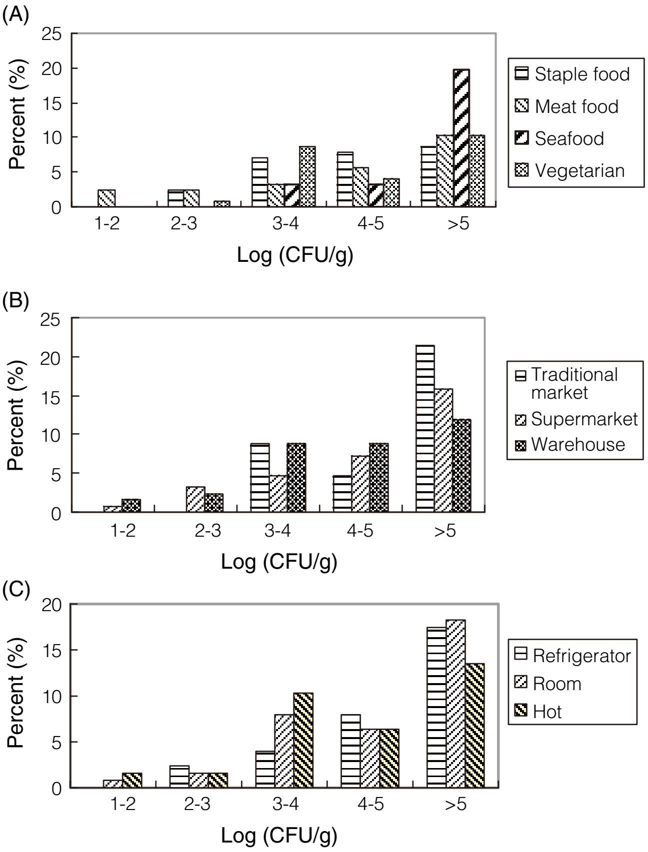

Figure 1. Distribution of aerobic plate count in ready-to-eat foods (A) different food types (B) different selling points (C) different selling temperature.

II. *Unsatisfactory Rates for Microbiological Qualities of RTE Food Products*

According to the revised Food Sanitation Standard[13] for RTE food products (without the need of cleaning, skinning, heating or cooking) of Taiwan, coliforms should not exceed 10 MPN/g. In addition, *E. coli* and pathogenic bacteria should be detected negatively. APC exceeding 5 log CFU/g was taken as the reference value to identify poor food microbiological quality. Figure 1 is the distribution of APC of the investigated RTE food products. Twenty five of seafood products contained APC greater than 5 log CFU/g, whereas staples, meat, and vegetarian food products had 13, 13 and 11 samples with APC in excess of 5 log CFU/g (Figure 1-A). RTE food products sold in the traditional markets had the highest frequency (27 items) of containing APC greater than 5 log CFU/g (Figure 1-B), whereas had 20 and 15 items of food products sold in the supermarkets and warehouse stores were detected to contain APC over 5 log CFU/g. Furthermore, room temperature storage resulted in the greatest APC counts (23 samples), followed by refrigerator (22 samples) and hot (17 samples) temperatures storages (Figure 1-C). The rates of noncompliance detected from various markets are presented in Table 4. The results indicated that the microbiological qualities of 23.8, 12.7 and 15.1% of RTE food products sold in the traditional

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markets, supermarkets and warehouse stores were unsatisfactory. The difference in noncompliance among the three places of sales was insignificant ($p > 0.05$). The rates of noncompliance of *E. coli* were 1.6 and 2.4% for RTE food products sold in supermarket and warehouse stores, respectively, showing no significant differences statistically ($p > 0.05$). However, the highest rate of noncompliance of *S. aureus* was found in the traditional market (19.0%), followed by the supermarkets (12.7%), with significant difference between these two places of sale ($p < 0.05$). The overall prevalence of noncompliance for coliform was in the range of 8~5%, depending on the types of food (Table 5). Incidences for noncompliance of *E. coli* were 0.8 and 3.2% for meat and seafood products, respectively. There was no statistically significant difference among the types of RTE food products in terms of coliform and *E. coli* counts ($p > 0.05$). These results were in agreement with that reported by Chiou[14]. Seafood products also showed the highest *S. aureus* contamination rate (15.9%) whereas 9.5% of staples and meat products were contaminated with this pathogen. Only 6.3% of vegetarian food products were contaminated, representing the lowest noncompliance rate ($p < 0.05$) (Table 5). Microbiological quality of RTE food products stored and sold at different temperatures was summarized in Table 6. Examination of RTE food products revealed that 23.0, 19.8 and 8.7% of foods stored at room, refrigerator and hot temperatures, respectively, were unacceptable to the governmental guideline ($p < 0.001$). Noncompliance rates of *E. coli* were 2.4 and 1.6%, respectively, for food products that were sold at refrigerator and room temperature. As for *S. aureus*, the rates of noncompliance were 8.7, 13.5 and 19.0% for food products stored at hot, refrigerator and room temperatures, respectively.

Table 4. Unsatisfactory rate of coliform, *E. coli* and *S. aureus* in RTE food products sold in different markets

Place	No. of samples	Unsatisfactory rate(%)[a]		
		Coliform	*E. coli*	*S. aureus*
Traditional markets	44	23.8	0.0	19.0
Supermarkets	40	12.7	1.6	12.7
Warehouse stores	42	15.1	2.4	9.5
p value[b]		0.0531	0.5234	0.0493*

[a]The value represents the unsatisfactory rate of a sample. The food sanitation standard for RTE foods is less than 10 MPN/g of coliform; *E. coli* and *S. aureus* are not detected.
[b]$p < 0.05$ was statistically significant.

Table 5. Unsatisfactory rate of coliform, *E. coli* and *S. aureus* in various RTE food products

Major ingredients	No. of samples	Unsatisfactory rate (%)[a]		
		Coliform	*E. coli*	*S. aureus*
Staple food	33	13.5	0.0	9.5
Meat food	30	15.9	0.8	9.5
Seafood	33	13.5	3.2	15.9
Vegetarian food	30	8.7	0.0	6.3
p value		0.2551	0.1170	0.0444[b]

[a]The value represents the unsatisfactory rate of a sample. The food sanitation standard for RTE foods is less than 10 MPN/g of coliform; *E. coli* and *S. aureus* are not detected.
[b]$p < 0.05$ was statistically significant.

Table 6. Unsatisfactory rate of coliform, *E. coli* and *S. aureus* in RTE food products at various selling temperature

Selling temperature	No. of samples	Unsatisfactory rate (%)[a]		
		Coliform	*E. coli*	*S. aureus*
Refrigerator[b]	40	19.8	2.4	13.5
Room[c]	44	23.0	1.6	19.0
Hot[d]	42	8.7	0.0	8.7
p value		0.0003[e]	0.4925	0.02781[e]

[a]The value represents the unsatisfactory rate of a sample. The food sanitation standard for RTE foods is less than 10 MPN/g of coliforms; *E. coli* and *S. aureus* are not detected.
[b]The range of low temperature was 5~7°C.
[c]The range of room temperature was 22~28°C.
[d]The range of hot temperature was 60~65°C.
[e]$p < 0.05$ was statistically significant.

DISCUSSION

RTE foods do not need to be reheated before consumption. A high APC, coliforms, or *E. coli* counts suggests contamination resulted from inappropriate processing, incomplete heating, or secondary contamination via contact with contaminated equipments such as chopping boards, knives, and serving wares, etc. APC lower than 5 log CFU/g is considered safe for consumption in Japan[10]. Additionally, the presence of *E. coli* in RTE food products indicates the possibility of secondary contamination. On the other hand, existence of *S. aureus* suggests poor hygiene practices of the operators, cross-contamination during preparation, or improper storage[15,16].

A study conducted in the United Kingdom showed that 94% of rice provided by restaurants and other take-away premises were of acceptable microbiological quality. However, 1% of the investigated samples contained greater than 5 log CFU/g of both *Bacillus* spp. and *Bacillus cereus*; *E. coli* was in amount greater than 4 log CFU/g which failed to meet the applicable standards for such food preparations therefore posed potential health hazard[16]. RTE foods sold in unsanitary locations are susceptible to contamination by flies and dust laden microorganisms. Umoh[6] found that RTE of street foods from stationary sellers without shelter had the highest frequency of contamination with *B. cereus* and *S. aureus* in Zaria, Nigeria. Similarly, our study revealed that all of the 126 examined RTE food products from all three types of market were detected to contain coliform while prevalence of *E. coli* was lower. Food products sold in supermarkets had the lowest incidence of contamination with *S. aureus*, possibly associated with higher food hygiene standards due to reduced manual handling by automated operation. In contrast to supermarkets, traditional markets in general have non-standardized personal hygiene practices and waste discard policies that complicated the overall sanitation of the food products. Operator should be aware of the high-risk conditions during food preparation[17].

Coliform and *E. coli* were the most common contaminating microorganisms for RTE foods because both were isolated from all 4 types of food products examined, especially coliform whose noncompliance rate was found to be as high as 8~15%. Fang *et al.*[18] reported that among the 18°C ready-to-eat ham and seafood products, 88% (ham) and 80% (seafood) were found to be contaminated with coliforms. The percentages were higher than that of RTE vegetable and meat products. For example, the microbiological quality of shrimp salad, roasted beef and bologna in Rutgers University dining halls had higher contamination than coleslaw, macaroni salad and potato salad[19]. Coliform on RTE food products reflected the recontamination caused by secondary processing and poor personal hygiene.

Most RTE cooked foods are generally prepared in bulk and displayed for whole-day sales at ambient temperature. Chiou[14] examined RTE food products kept hot on the sale and found the incidence rates of APC, coliform and *E. coli* in 300 samples to be 17.7%, 20.3% and 8%, respectively, not meeting the microbiological standards of the Republic of China Government. Both coliform and *S. aureus* counts exceeded the maximum permissible levels when they were stored at room temperature, whilst hot kept food products exhibited the lowest rate of noncompliance among the three temperature levels. *S. aureus* in RTE foods presents a risk of causing food-borne intoxication due to handling contamination and prolonged storage periods without reheating[12,20].

Previous research pointed out that it is plausible to achieve low contamination street-vended food supplies if proper control points are successfully established[21]. In order to meet the consumer demand for RTE food products, a large variety of convenient food products are available in the market. However, the handling-free property of RTE foods makes the food hygiene a critical requirement to safeguard the consumers' health. It is practical to employ Good Hygiene Practices to minimize, if not eliminate, the risk posed by secondary contamination[7]. Furthermore, a proper hazard analysis critical control point (HACCP) can be implemented to perform hazard analysis on RTE food products at critical points to monitor and to control the microbiological quality of such food products.

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