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Temperature control efficacy of retail refrigeration equipment

J. Lundén [a,*], V. Vanhanen [b], T. Myllymäki [b], E. Laamanen [b], K. Kotilainen [b], K. Hemminki [b]

[a] Department of Food Hygiene and Environmental Health, Faculty of Veterinary Medicine, P.O. Box 66, 00014 University of Helsinki, Finland
[b] Food and Environmental Health Unit, Section of Health, P.O. Box 210, 02070 City of Espoo, Finland

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ABSTRACT

Temperature control of food products in retail food stores (food stores) is essential for food safety. The food business operator (FBO) must ensure that the product temperatures comply with food regulations. This study investigated the temperatures of products in 32 food stores and the relationship between the product temperature with the temperature of the refrigeration equipment (open front) and the temperature settings. The FBOs awareness of the equipment and product temperatures and the equipment temperature settings (temperature setpoint, alarm setpoint, timing for alarm to go off) were also investigated. The food stores represented four nationwide chain-store groups in Finland. The study included four categories of food products namely: fresh fish, minced meat, vacuum packed ready-to-eat processed fish and other ready-to-eat products, all of which are easily perishable products. Vacuum packed fish products and other ready-to-eat products are also sensitive to *Listeria monocytogenes* contamination. The temperatures of the products ($n = 84$) and refrigeration equipment ($n = 86$) were measured by a temperature data logger by the health inspector for 24 h.

Temperature violations were observed in 50% of the products and 17.9% of the products exceeded the temperature limit by over 3 °C for more than 30 min. Products that were most often in noncompliance were fresh fish and vacuum packed processed fish products. Temperature violations were observed in food stores in all four chain-store groups and no significant difference between the chain-store groups was observed. The temperature of the equipment as measured by the refrigeration equipment's fixed thermometers differed significantly from the temperatures of the products. Moreover, no significant correlation was found between the equipment temperatures (fixed thermometer) and the products with the exception of minced meat. These results highlight, that the product temperature could not be reliably determined by the equipment's fixed thermometer.

There was a lack of awareness of temperature settings in all chain-store groups. Only three stores (9.4%) were aware of all the settings of the inspected equipment. The results show that the FBOs own-check of equipment and product temperatures is not functioning correctly in food stores. This can have serious consequences for food safety. FBOs, equipment manufacturers, monitoring system providers and official food control authorities should take active measures to improve the situation.

1. Introduction

The actions taken in retail food stores have important effects on food safety, specially food stores selling products that need cold holding must have the appropriate refrigeration equipment and a functioning own-check system (self-regulation system) (Anonymous, 2011). However, studies indicate that the temperature of refrigeration equipment may not always be adequate in food stores (González, Vitas, Díes-Leturia, & García-Jalón, 2013; Likar & Jevšnik, 2006; Lundén, 2013; Lundén, Vanhanen, Kotilainen, & Hemminki, 2014; Morelli, Noel, Rosset, & Poumeyrol, 2012) despite having their own-check system (Lundén et al., 2014).

It is important that the temperature of the refrigeration equipment is adequate, but it is even more important to make sure that the food product is at the correct temperature. However, it is not obligatory to measure the actual temperature of the food products in the own-check according to Finnish legislation (Anonymous, 2011), it is only the equipment temperature that the food business operators (FBO) are obliged to monitor. The temperatures of the refrigeration equipment and the product they contain are not necessarily the same (González et al., 2013; Lundén et al., 2014), which should be considered by the FBO and the official food control authority.

* Corresponding author. Tel.: +358 9 19157148; fax: +358 9 19157170.
E-mail address: janne.lunden@helsinki.fi (J. Lundén).

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Previous studies have shown that the required temperatures of products may be violated for some time (Likar & Jevšnik, 2006; Lundén et al., 2014; Morelli et al., 2012). The magnitude of possible temperature violations of products in food stores is not well known, because FBOs or official control normally only make a spot-check observation of the product temperature (Anonymous, 2014). The magnitude and duration of possible temperature violations is essential for product safety and should be investigated on the retail level.

The temperature of the equipment is especially important when storing products that are easily perishable and products that may cause a serious food poisoning. Examples of especially sensitive products include vacuum packed processed fish products that are commonly contaminated with *Listeria monocytogenes* (Kramarenko et al., 2013; Thisted-Lambertz et al., 2012). Vacuum packed processed fish products are suspected to have a major role in human listerosis cases in Finland (Anonymous, 2013). Such products usually have long shelf-lives and may be stored at retail food stores' open front equipment for considerable periods of time. Therefore the cold holding of such products should also be strictly monitored at retail level.

The FBOs should have the appropriate means to make sure that the temperature of the equipment is correct. This necessitates the accurate measurement of equipment and an adequate frequency of measurements. The FBO should be aware of the equipment temperature settings and also alarm settings in order to react when needed. However, the FBO's awareness of the equipment settings and product temperatures has not been investigated.

The aim of this study was to investigate the extent and magnitude of noncompliance in the temperature of food products in retail food stores and to elucidate the relationship between the temperatures of the refrigeration equipment and of the products. The FBO's knowledge of the temperature settings of the equipment was also investigated.

2. Material and methods

2.1. Retail food stores

Thirty two retail food stores (grocery shops) located in a local food control unit (Food and Environmental Health Unit, Region of Espoo, Finland) were included in the study. Four different chain-store groups (grocery multiple retailers) were represented in the study (16, 12, 3 and 1 stores, respectively) of which two are the biggest chain-store groups in Finland. The stores were categorized into two groups according to size: 20 small stores and 12 large stores (supermarkets) for further analysis.

2.2. Inspections

Inspectors inspected the food stores during January–March of 2012. The inspectors used temperature data loggers (Temperature logger iButton DS1922L, Maxim Dallas Semiconductor) to measure the temperatures of the refrigeration equipment (air temperature) and also of the products. The temperatures of two-to-three self-service refrigeration equipment (open front) in every food store were determined. The temperature of one product within every refrigeration equipment was measured. In total, the temperatures of 86 refrigeration equipment and 84 food products (Table 1) were measured (two products were misplaced during the measurements). The products included in the study were fresh fish, minced meat, vacuum packed processed fish (gravad or cold smoked fish) and other ready-to-eat-foods. These are products that are easily perishable, and require low storage temperatures (fresh fish max 2 °C, vacuum packed processed fish max 3 °C, minced meat max 4 °C and ready-to-eat products max 6 °C) according to Finnish regulations (Anonymous, 2011, 2014). Vacuum packed processed fish, in particular but also other ready-to-eat products are considered to cause a *L. monocytogenes* risk. The results of the temperature violations are presented as temperatures that exceed the temperature limit by over 1 °C and by over 3 °C for at least 30 min. The Finnish regulations stipulate that the temperature of the product can exceed the product temperature limit by a maximum of 3 °C for only a short period of time (Anonymous, 2011). The short period of time is defined in the instructions of National Food Safety Authority (Evira) to be 24 h (Anonymous, 2014). In this study 30 min was chosen as a time limit because experience from official control has shown that temperature violations of this magnitude can influence the product temperature and it has been used as time limit in an earlier study (Lundén et al., 2014).

The temperature data logger was placed within the product package and pushed into the product. The product located in the middle of the equipment close to the back wall. Another logger, that measured the temperature of the equipment's air, was placed next to the product between the product and the back wall of the equipment. The loggers were located close to the back wall of the equipment so that the loggers would not be misplaced by customers. The temperatures were measured for 24 h with 15 min intervals. The temperature indicated by the equipment's own thermometer (fixed thermometer, digital display on the equipment) was documented once during the inspection.

The food stores were asked to show (or to tell the inspector) the temperature settings of the refrigeration equipment including the temperature of the equipment at the time of inspection, the temperature setpoint, alarm setpoint and the time from reaching the alarm setpoint to the triggering of the alarm.

2.3. Statistical analysis

The statistical significance of differences between the temperature that was indicated by the fixed thermometer, the mean temperatures of the equipment as indicated by the logger and the mean temperatures of the product was analysed by the Mann–

Table 1
Temperature violations of food products in food stores ($n = 32$) during a 24 h (1440 min) measurement.

Food type (number of food products)	Proportion of products exceeding temperature limit by >1 °C %	Duration of time (min) when products exceeded temperature limit by >1 °C Mean (min–max)	Proportion of time when products exceeded temperature limit by >1 °C % of 24 h	Proportion of products exceeding the temperature limit by >3 °C for >30 min %
Fresh fish (19)	89.5	781 (15–1440)	54.2	52.6
Processed fish (8)[a]	50.0	641 (45–1395)	44.5	25.0
Minced meat (30)	40.0	249 (15–1425)	17.3	10.0
Ready-to-eat (27)[b]	33.3	308 (15–1395)	21.4	0
Total (84)	50.0	–	–	17.9

[a] Vacuum packed processed fish (ready-to-eat).
[b] Ready-to-eat product other than vacuum packed processed fish.