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Effects of processing and storage of dairy products on lindane residues and metabolites

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Abstract

Residue levels of lindane and its metabolites were monitored in 25 samples of raw and sterilized milk, yoghurt, Domiati & Ras cheese collected from different regions in the Great Cairo Governorates. The concentrations of lindane followed the order: raw milk > Domiati cheese > sterilized milk > yoghurt = Ras cheese. Most samples were found to contain three or more metabolites at different levels. Heat treatments (pasteurization, boiling and sterilization) reduced lindane levels. The reduction percentages were 65.0–73.0, 75.0–85.4, and 84.4% for lindane content and 0.1–43.0, 37.3–55.4, and 76.6% for total of lindane and its metabolites on pasteurization, boiling, and sterilization, respectively. A gradual reduction of lindane ranging from 1.4–8.9% was observed during the manufacture and storage of yoghurt for three days in a refrigerator. The reduction of lindane was higher in Domiati cheese made by acid-enzyme coagulation than that made by enzyme coagulation. On the other hand, the manufacturing process of Ras cheese removed 36.7% lindane after storage (ripening) periods of 6 months. This may be due to the effect of microorganisms during storage. © 1999 Published by Elsevier Science Ltd. All rights reserved.

Keywords: Dairy products; Lindane; Metabolites

1. Introduction

No one can dispute the great contribution that pesticides have made to control of insect-borne deseases, to increased agricultural production and to the control of household pests, thus improving the quality of living all over the world. Nevertheless, the almost universal occurrence of pesticide residues in soil, water, air and living organisms has led to the view that pesticides are environmental contaminants or, more spectacularly in some of the popular press, insidious, uncontrollable poisons (Mitchell, 1966). The chlorinated hydrocarbon insecticides have attracted particular attention because of their persistence and adverse effects on some birds, animal and aquatic ecosystems. Milk and milk products are a main constituent of the daily diet, especially for vulnerable groups such as infants, school age children and old age (Davies, Freed & Whittemore, 1986). Milk can be contaminated with pesticide residues from a variety of sources. The major source of organochlorine residues is from fodder and soil (Snelson & Tuinstra, 1979). Thus, monitoring pesticide residues in milk is of utmost importance (WHO, 1972; GEMS, 1991). The residues of organochlorine compounds in milk and milk products have been studied in many countries (FAO/WHO, 1981; Al-Omar, Abdul-Galil, Tawfik & Al-Bassomy, 1986; Abdel-Gawaad, Seleim & Ezz, 1991). Lindane is one of the organochlorine pesticides which has been extensively used as a preharvest treatment of fruits, vegetables, and other edible crops. Lindane is used also on forage crops and cereals by application to plants or soil and as a seed dressing, alone or in combination with fungicides (WHO, 1982).

Several cases of fatal poisoning and numerous cases of non-fatal illness caused by or ascribed to lindane have been reported. These incidents were either accidental, (suicide) or due to gross neglect of safety precautions. In many of these cases, the effects ascribed to lindane were more likely to have been due, in total or in part, to other substances. A critical review of these cases is provided by Hayes (1982). Lindane is circulating in the environment and is present in food chains, so that humans will continue to be exposed. The daily intake and total exposure of the general population are decreasing gradually; however, they are clearly below the advised acceptable daily intake and are of no concern to public health (International Programme on Chemical Safety, 1991).

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Several investigators have attempted to reduce the organochlorine contents of dairy products by certain processing techniques, chemical treatments of milk or by administering drugs (Guingamp & Alais, 1974; Molochnikov & Mochalov, 1976; Abdou, Abdel-Gawaad, Abo-El-Amaiem & El-Alfy, 1983; Abou-Donia, Abdel-Shahaid, Shaker, Salam & Ismail, 1985; Abou-Arab, 1991). Consequently, there is a lack of information regarding the effect of manufacturing and storage on the distribution and concentration levels of lindane and its metabolites.

Liquid milk, yoghurt, Domiati and Ras cheese are popular dairy products among Egyptian consumers. Thus, the aim of this investigation was to determine the extent of lindane and its metabolic residues in milk and milk products collected from different regions in the Great Cairo Governorates. The effect of heat treatments such as pasteurization, boiling, and sterilization on lindane residues were also elucidated. The effects of manufacturing processes of yoghurt, Domiati and Ras cheese on the degradation of lindane and its metabolites were also studied.

2. Materials and methods

2.1. Materials

Twenty-five samples of raw and sterilized milk, yoghurt, Domiati and Ras cheese were collected from local markets in the Great Cairo Governorates.

2.2. Heat processing

Raw milk was contaminated with lindane at a level of 1 mg kg^{-1} fat, then exposed to the following heat treatments: pasteurization at 72°C/15 s and at 63°C/30 min, boiling for 5, 10 and 15 min. Sterilization was carried out at 121°C/15 min by autoclave.

2.3. Yoghurt making

Milk was heated at 80–82°C/20 min and cooled to 40°C. The heated milk was contaminated with 1 mg lindane/kg fat, then inoculated with 2% starter (mixture of *Lactobacillus bulgaricus* and *Streptococcus thermophilus*) and incubated at 40°C for 3 h as described by the Egyptian Organization for Standardization (1970). Yoghurt was stored for 3 days in the refrigerator.

2.4. Domiati cheese making

Domiati cheese was made from contaminated milk (1 mg lindane/kg fat) after heating (80°C and cooled to 40°C) by acid-enzyme coagulation and enzyme coagulation according to Fahmy and Sharara (1950).

2.5. Ras cheese making

Ras cheese was manufactured by the conventional method described by Abd-El-Tawab (1963) from contaminated milk with 1 mg lindane/kg fat. A common starter culture was used. Pure strains of *S. thermophilus* (EMC 1225) and *L. bulgaricus* (EMC 1322) were obtained from the Egypt Microbial Collection at the Microbiological Resource Centre (MIRCN), Faculty of Agriculture, Ain-Shams University. Animal rennet powder obtained from CH-Hansen Laboratory, Denmark, was used as a coagulant. The cheese moulds were coated with paraffin wax and stored for ripening at 12°C. Samples were taken for analysis during the different steps of manufacturing and storage periods for 6 months.

2.6. Pesticide analysis

Lindane and its metabolites were extracted from different samples using diethyl ether, petroleum ether, and acetonitrile. The extracts were purified using a florisil column according to AOAC (1995) and the Pesticide Analytical Manual (1991). Aliquots of 1–2 μl of extracts were injected into a Hewlett–Packard gas chromatograph Model 5890 Series 11 equipped with Ni^{63} electron capture detector and integrator 3395, fitted with HP-1 capillary column (methyl silicon gum), 30 m×0.25 mm, 0.2 μm film thickness. The column oven temperature was programmed from 80 to 160°C at a rate of 3° min^{-1}, held for 2 min, then increased to 220°C at a rate of 5°C min^{-1} and held for 20 min. Injection and detector temperatures were 220 and 300°C, respectively. Pesticide standards (2,6-dichlorophenol; 2,3,5-trichlorophenol; 3,4-dichlorophenol; pentachlorophenol; hexachlorobenzene; 2,5-dichlorophenol and 2,4-dichlorophenol) were provided by the Environmental Protection Agency (EPA).

3. Results and discussion

3.1. Monitoring of lindane and its metabolites in milk and dairy products

The concentrations of lindane and its metabolites in collected samples of raw and sterilized milk, yoghurt, Domiati and Ras cheese are shown in Table 1. Ten samples of both raw and sterilized milk contained lindane residues ranging from 0.004 to 0.042 and 0.001 to 0.022 mg kg^{-1} fat, respectively, while it was found in 7, 11 and 4 samples of yoghurt, Domiati and Ras cheese, respectively. The concentrations of lindane residues in positive samples of yoghurt, Domiati and Ras cheese were 0.001–0.014, 0.006–0.041, and 0.001–0.003 mg kg^{-1} fat, respectively. Although residues of lindane were detected only in some of the tested samples, 5, 4, 1 and 6 samples of raw milk, sterilized milk, yoghurt and Domiati cheese, respectively, showed values above the maximum residue limits (MRLs) for lindane (0.01 mg kg^{-1} fat) recommended by FAO/WHO (1993). Concentrations of lindane in different samples followed the order: raw milk > Domiati cheese > sterilized milk > yoghurt > Ras cheese. Table 1 indicates also, that eight lindane metabolites were identified and quantified in raw milk and Domiati cheese at different levels, namely, 2,6-dichlorophenol; 2,3,5-trichlorophenol; 2,3,4-trichlorophenol; 3,4-dichlorophenol; pentachlorophenol; hexachlorobenzene, 2,5-dichlorophenol, and 2,4-dichlorophenol. Three metabolites were detected in sterilized milk and Ras cheese, namely, 2,6-dichlorophenol, 2,3,5-trichlorophenol and 2,3,4-trichlorophenol. However, hexachlorobenzene, 2,5-dichlorophenol and 2,4-dichlorophenol were not detected in sterilized milk, yoghurt or Ras cheese. Moreover, 2, 8, 1 and 16 samples of raw milk, sterilized milk, yoghurt and Ras cheese, respectively, were free from residues. The levels of lindane in the raw milk samples in this investigation were lower than that obtained by Cerutti, Zappavigna, Geroso & Proverbio (1975), Wedberg, Moore, Amore & McAvoy (1978), Laugel (1981), Izomerov (1983), Rhone-Poulenc Agrochimie (1986), Rappe, Nygrem, Lindstrom, Buser, Blaser & Wüthrich (1987), Steering Group on Food Surveillance (1989) and Abou-Arab (1991). However, Cerutti et al. (1975) reported that lindane levels in yoghurt ranged from 0.004 to 0.01 mg kg^{-1} fat. On the other hand, Abou-Arab (1991) found that 66% of Domiati cheese samples contained lindane (0.130 mg kg^{-1} fat on average).

The Steering Group on Food Surveillance (1989) detected lindane at a concentration of 0.01–0.03 mg kg^{-1} fat in about 50% of samples of retail milk and dairy products collected in 1984–1987 in the UK. According to the MRLs established by the Codex Committee for Pesticide Residues (1984), 77% of raw milk samples from Beni-Suef (Egypt) exceeded the MRLs for lindane (Dogheim, Nasr, Almaz & El-Tohamy, 1990). Martin and Duggan (1968) found gamma-HCH at levels of 0.09 mg kg^{-1} in dairy products collected from 30 markets in 27 cities in the USA in 1966–1967. No gamma-HCH at levels of 0.01–0.1 mg kg^{-1} were found in 99% of samples of cows milk and manufactured milk products from Illinois, USA (Wedberg, Moore, Amore & McAvoy, 1978). In milk samples collected during Spring 1983 from 359 bulk transporters, representing 16 municipalities of Ontario, Canada, gamma-HCH was

Table 1
Lindane levels and its metabolites in milk and dairy products (mg kg^{-1} fat)

Products	1[a] (0.01 mg kg^{-1} fat)	2	3	4	5	6	7	8	9	No. of samples with no residues
Raw milk										
Number positive	10	16	7	2	3	2	2	1	1	
Number > MRLS	5	–	–	–	–	–	–	–	–	
Range	0.004–0.042	0.001–0.014	0.004–0.009	0.001–0.011	0.004–0.008	0.006–0.009	0.001–0.009	0.006	0.004	2
Mean	0.016	0.006	0.006	0.006	0.006	0.008	0.008	0.006	0.004	
Sterilized milk										
Number positive	10	7	5	4	0	0	0	0	0	
Number > MRLs	4	–	–	–	–	–	–	–	–	
Range	0.001–0.022	0.001–0.009	0.002–0.006	0.003–0.004	–	–	–	–	–	8
Mean	0.010	0.005	0.004	0.004	–	–	–	–	–	
Yoghurt										
Number positive	7	4	3	3	4	5	0	0	0	
Number > MRLs	1	–	–	–	–	–	–	–	–	
Range	0.001–0.014	0.004–0.009	0.004–0.008	0.001–0.008	0.001–0.007	0.001–0.008	–	–	–	
Mean	0.005	0.006	0.006	0.005	0.004	0.005	–	–	–	
Domiati cheese										
Number positive	11	9	9	5	4	5	4	3	2	
Number > MRLs	6	–	–	–	–	–	–	–	–	
Range	0.006–0.041	0.004–0.014	0.001–0.014	0.001–0.006	0.004–0.006	0.001–0.016	0.006–0.018	0.001–0.004	0.004–0.009	0
Mean	0.015	0.008	0.006	0.004	0.005	0.006	0.011	0.003	0.007	
Ras cheese										
Number positive	4	2	2	2	–	–	–	–	–	16
Number > MRLs	–	–	–	–	–	–	–	–	–	
Range	0.001–0.003	0.001–0.002	0.001–0.003	0.001–0.003	–	–	–	–	–	
Mean	0.002	0.015	0.002	0.002	–	–	–	–	–	

[a] MRLS of lindane.

1. Lindane; 2. 2,6-Dichlorophenol; 3. 2,3,5-Trichlorophenol; 4. 2,4-Trichlorophenol; 5. 3,4-Dichlorophenol; 6. Pentachlorophenol; 7. Hexachlorobenzene; 8. 2,5-Dichlorophenol; 9. 2,4-Dichlorophenol.

found in 68% of the samples at a mean concentration of 4.0 g kg^{-1} butter fat (Frank, Braun, Sirons, Rasper, & Ward, 1985). Six samples of cows' milk, from six loations in Switzerland, contained 3.0–5.1 mg kg^{-1} on a fat basis (Rappe, Nygrem, Lindstrom, Buser, Blaser & Wüthrich, 1987). In 1967–1970, in the Ukraine, gamma-HCH was found in cows milk at an average concentration of 0.6 mg $litre^{-1}$ (Izomerov, 1983). In the USSR, the following concentrations were found: milk and milk products, 0.055 ± 0.005 mg kg^{-1} and butter, 0.003 ± 0.002 mg kg^{-1}. Concentrations of gamma-HCH were measured in 1250 samples of milk and other dairy products in France in 1970–1977 and in 1981. In the first period, the gamma-HCH concentration was < 0.1 mg kg^{-1} of fat; by 1981, the levels had declined to < 0.03 mg kg^{-1} of fat (Laugel, 1981; Rhone-Poulenc Agrochimie, 1986).

The differences in lindane levels (and its metabolites) in dairy products depend mainly on the concentrations of residues detected in raw milk. Milk and milk products can be contaminated with residues of organochlorine pesticides from a variety of sources. The major source of organochlorine residues is from fodder and soil (Snelson & Tuinstra, 1979).

3.2. *Effect of heat treatments on lindane and its metabolites*

The effect of heat treatments, such as pasteurization and boiling, on lindane and its metabolites are given in Table 2. Pasteurization at 72°C/15 s caused a reduction in lindane of 65% but only about 0.1% in total lindane and its metabolites, while that carried out at 63°C/30 min caused approximately 73% reduction in lindane and about 43% in total lindane and its metabolites. Boiling on the other hand, for 5, 10 and 15 min, reduced lindane levels by 75, 79.6 and 85.4%, respectively. A reduction in lindane by 84.4% was observed in milk after sterilization at 121°C/15 min. Although residues of lindane were reduced by heat treatments, many metabolites were detected at different levels. Li, Bradley, & Schultz (1970) investigated the fate of organochlorine pesticides during the processing of milk into pasteurized whole milk, 30% cream, butter, spray whole milk and sterilized condensed whole milk. The results indicate that, in general, the pesticides used were very stable for ordinary processing operations and remained essentially unchanged even after storage at room temperatures for 6 months. Guingamp & Alais (1974) studied the degradation of organochlorine pesticides in milk heated in sealed tubes at 150°C up to 350°C for 1–5 h. They found that on heating up to 200°C, lindane was destroyed after 1 h and complete destruction occurred after 3 h. On the other hand, Molochnikov & Mochalov (1976) reported that flash pasteurization at 85–90°C did not affect lindane levels and other residues.

3.3. *Effect of manufacture and storage of yoghurt, Domiati and Ras cheese on lindane and its metabolites*

The concentrations of lindane and its metabolites in yoghurt, Domiati and Ras cheese are shown in Table 3. Data revealed that, the levels of lindane in yoghurt made from contaminated milk decreased by 1.4% just after processing (fresh). However, the reduction increased gradually during storage in the refrigerator for 1, 2 and 3 days by 2, 3.6 and 8.6%, respectively. The reduction of lindane in yoghurt may be due to the growth of yoghurt starter. Similar findings were reported by Abou-Arab (1991). However, a reduction of 34% lindane, mentioned by El-Alfy (1981) during manufacture of yoghurt may be mainly due to the associated effects of a heating step before inoculation with the starter culture. On the other hand, in the presence of lindane at concentrations of 0.01, 0.1 and 1.0 ppm, the growth rate of *Streptococcus lactis* and acid production were not significantly affected. However, the growth rate of *S. lactis* was noticeably delayed in the presence of lindane at concentrations over 2.0 ppm (Abdou, Abdel-Gawaad, Abo-El-Amaiem & El-Alfy, 1983 & Abou-Arab, 1991).

Table 2
Effect of heat treatments on lindane and its metabolites (mg kg^{-1} fat)

Treatment	1	2	3	4	5	6	7	8	9	Total
Raw milk	1.000	0.004	–	0.006	–	–	–	–	–	1.01
Pasteurization at:										
72°C/15 s	0.350	0.286	0.146	0.038	0.189	0.009	0.014	–	–	1.009
63°C/30 min	0.271	0.106	0.098	0.064	0.009	0.014	0.004	0.004	–	0.575
Boiling for:										
Just after boiling	0.360	0.168	0.246	0.096	0.104	–	–	0.068	0.006	1.048
5 min	0.250	0.203	0.106	0.068	0.006	–	–	–	–	0.633
10 min	0.204	0.201	0106	0.046	–	–	–	–	–	0.557
15 min	0.146	0.304	–	–	–	–	–	–	–	0.450
Sterilization at:										
121°C/15 min	0.156	0.023	0.014	0.019	0.014	–	0.003	–	0.006	0.236

1. Lindane; 2. 2,6-Dichlorophenol; 3. 2,3,5-Trichlorophenol; 4. 2,3,4-Trichlorophenol; 5. 3,4-Dichlorophenol; 6. Pentachlorophenol; 7. Hexachlorobenzene; 8. 2,5-Dichlorophenol; 9. 2,4-Dichlorophenol.

Table 3
Effect of manufacturing process and storage of yoghurt, Domiati and Ras cheese on lindane residues and metabolites (mg kg^{-1} fat)

Product	1	2	3	4	5	6	7	8	9	Total
Raw milk	1.000	0.004	–	0.006	–	–	–	–	–	1.01
Yoghurt:										
Fresh	0.986	0.003	–	0.004	–	–	–	0.005	–	0.998
After 1 day	0.980	–	–	–	–	–	–	–	–	0.980
After 2 days	0.964	0.001	–	0.002	–	–	–	–	–	0.967
After 3 days	0.914	0.002	–	0.003	–	–	–	–	–	0.919
Domiati cheese:										
Enzyme Coagulation	0.986	0.003	–	0.007	–	–	–	0.006	–	1.002
Acid-enzyme Coagulation	0.964	0.002	–	0.008	–	–	–	0.009	–	0.983
Ras cheese:										
Pasterurized milk	0.364	0.209	0.094	0.198	0.104	–	–	–	–	0.969
Curd	0.348	0.206	0.080	0.190	0.101	–	–	–	–	0.925
Whey at dipping	–	–	–	–	–	–	–	–	–	–
Whey from pressing	–	–	–	–	–	–	–	–	–	–
Cheese after pressing	0.340	0.210	0.080	0.181	0.104	–	–	–	–	0.915
Storage period (month)										
1	0.340	0.215	0.081	0.184	0.091	–	–	–	–	0.911
2	0.300	0.220	0.094	0.178	0.084	–	–	–	–	2.876
3	0.250	0.241	0.081	0.169	0.069	–	–	–	–	3.810
4	0.155	0.255	0.085	0.206	0.094	–	–	–	–	4.795
5	0.112	0.240	0.094	0.208	0.055	–	–	–	–	5.709
6	0.084	0.200	0.090	0.199	0.066	–	–	–	–	6.639

1. Lindane; 2. 2,6-Dichlorophenol; 3. 2,3,5-Trichlorophenol; 4. 2,3,4-Trichlorophenol; 5. 3,4-Dichlorophenol; 6. Pentachlorophenol; 7. Hexachlorobenzene; 8. 2,5-Dichlorophenol; 9. 2,4-Dichlorophenol.

Table 3 shows the distribution of lindane and its metabolites in Domiati cheese made from contaminated milk. It is clear that cheese made by acid-enzyme coagulation reduced lindane content more than cheese made by enzyme coagulation (i.e. 3.6 and 1.4%, respectively). These results are in good agreement with that obtained by El-Alfy (1981) and Abou-Donia, Abdel-Shahaid, Shaker, Salam & Ismail (1985). Moreover, Langlois, Liska & Hill (1964) found that more lindane than DDT was found in whey during manufacture of Swiss-type cheese. This helps to explain why the curd of cheese manufactured from milk containing lindane contains less insecticide than that from milk containing DDT. This also suggests that lindane is more soluble in whey than DDT.

The distributions of lindane and its metabolites in Ras cheese made from contaminated milk (with 1 mg lindane/kg fat) are shown in Table 3. Pasteurization at 72°C caused a reduction in lindane by 63.6% and in total lindane and its metabolites by 3.1%. This finding is in harmony with results obtained by Guingamp & Alais (1974) who reported that heat treatment lowered the lindane levels in milk. Whey from cheese after pressing contained small amounts of lindane and its metabolites (0.01 mg kg^{-1}. This may be attributed to the absorption of lindane by the coagulated milk protein or its association with that portion of milk fat normally found in whey (Montoure & Muldoon, 1968). However, the remaining level of total lindane and its metabolites after pressing was 91.5% in cheese made from contaminated milk. These results indicate that lindane is very resistant to processing techniques. Most organoclilorines, such as lindane and its metabolites are lipid-soluble; thus they have been more frequently found in fatty portions of foods. So residue levels of lindane are much higher in cream, butter and cheese than skim milk and whey (Mann, Carter & Ely, 1950). Storage (ripening) periods for 6 months causes 36.7% reduction in total lindane and its metabolites. This may be due to the effect of ripening microorganisms during storage. The reduction of total lindane during the storage period is 30.2%, based on the level of lindane and its metabolites in cheese made from contaminated milk, just after pressing. These results agree with those obtained by Montoure & Muldoon (1968) and Gertig & Moruszewska (1973).

The metabolism of lindane has been investigated in bacteria, and fungi. Chlorocycloalkenes, chlorobenzenes, and chlorophenols were found to be metabolic intermediates, and carbon dioxide to be the end-product. Volatile, chlorine-free hydrocarbons were also found (Haider, Jagnow, Kohnen & Lim, 1974; Haider, Jagnow & Rohr, 1975). Mixed populations of bacteria metabolize lindane to gamma-PCCH, alpha-, beta-, or gamma-3,4,5,6-tetrachloro-1-cyclohexane (TCCH), pentachlorobenzene, 1,2,3,4-,1,2,3,5-, or 1,2,4,5-tetrachlorobenzene, 1,2,4- or 1,3,5-trichlorobenzene, 1,2-and 1,4-dichlorobenzene, as well as carbon dioxide (Yule, Chiba & Morley, 1967; Haider, Jagnow, Kohnen & Lim, 1974, Haider, Jagnow & Rohr, 1976; Kohnen, Haider & Jagnow, 1975; Mathur & Saha, 1975; Tu, 1975; Jagnow, Haider & Ellwardt, 1977; Mathur & Saha, 1977; and Vonk & Quirijns, 1979). Metabolites of lindane were identified as PCCH and TCCH in populations of *Escherichia coli* (Francis, Spanggord & Ouchi, 1975; Vonk & Quirijns, 1979). PCCH, TCCH, 1,2,3,4-tetrachlorobenzene, and carbon dioxide were identified in *Pseudomonas* sp. (Benezet & Matsumura, 1973; Matsumura, Benezel & Patil, 1976; Engst, Macholz & Kujawa, 1979), and TCCH, 1,2,4-trichlorobenzene, and 1,4-dichlorobenzene in *Clostridium* sp. (Heritage & MacRae, 1977a,b; Ohisa & Yamaguchi, 1978; Ohisa, Yamaguchi & Kurihara, 1980; Ohisa, Kurihara & Nakajima, 1982).

Although the levels of lindane were reduced, other metabolites were detected in yoghurt, Domiati and Ras cheese at different levels, namely 2,6-dichlorophenol, 2,3,4-trichlorophenol and 2,5-dichlorophenol. These metabolites may be more toxic than lindane.

All collected samples of milk and milk products were found to contain lindane or its metabolites at different levels. The concentrations of lindane followed the order: raw milk > Domiati cheese > sterilized milk > yoghurt > Ras cheese. Heat treatments such as pasteurization, boiling and sterilization reduced lindane from 64 to 85.4% in milk. On the other hand, the manufacturing process of yoghurt caused a gradual reduction of lindane during storage for three days in a refrigerator. The reduction of lindane was higher in cheese made by acid-enzyme coagulation than that made by enzyme coagulation. However, the manufacturing process of Ras cheese removed only 36.7% lindane and its metabolites from the contaminated milk. The reduction of lindane in Ras cheese may be attributed to the microorganisms in ripening cheese as well as the absorption of pesticide residues and interference with the cellular metabolism of microorganisms (Chacko & Lackwood, 1967, Kim & Harmon, 1970; Hantke & Bradley, 1972).

According to these results, consumption of heat-treated milk and dairy products may be more safe than liquid milk.

In conclusion, there is an urgent need for an investigation into the whole matter of pesticide residues in milk and milk products, especially the effect of direct application of pesticides, the follow-up of cases where tolerance limits are exceeded and the fate of organochlorine pesticides during the processing of milk.

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