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THE INFLUENCE OF VARIOUS PRODUCTION PROCESSES ON THE MICROBIOLOGY OF MANUFACTURED MEAT PRODUCTS

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OPSOMMING: DIE INVLOED VAN VERSKEIE PRODUKSIEPROSESSE OP DIE MIKROBIOLOGIE VAN VERVAARDIGDE VLEISPRODUKTE

In 'n opname by 'n vleisverwerkingsfabriek is op verskillende plekke langs verskillende produksielyne agarworsmonsters geneem van vyf verskillende vervaardigde produkte te wete spek, varkwors, weense worsies, russiese worsies en ham. In die opname is mesofiele (37 ^{o}C/24 h) sowel as psigrotrofe organismes (5 ^{o}C/7 dae) gemonitor. Daar is gevind dat mikrobetellings gedurende produksie aansienlik styg as gevolg van 'n reeks faktore waarvan die belangrikste waarskynlik hantering is. Hierdie aanvanklike tellings van die onbehandelde produkte wat volgens Deense standaarde hoog is, word egter telkens met behulp van 'n berokings- of gaarmaakproses verminder tot op 'n aanvaarbare vlak van minder as 500 bakterieë cm $^{-2}$. Die uitsondering in die geval was varkwors waar 'n hitteproses tydens prosessering afwesig was.

SUMMARY:

In a survey at a meat processing factory agar sausage samples were taken at different positions on various production lines of several manufactured products viz. bacon, pork sausages, vienna sausages, russian sausages and hams. Mesophiles (37 ^{o}C/24 h) as well as psychrotrophs (5 ^{o}C/7 days) were monitored in this survey. A considerable increase in microbial counts was found for all the products during their production processes. The main cause for this increase was most probably handling during processing. The counts of the untreated products which were relatively high, according to Danish standards, were decreased by means of either a cooking or a smoking process. This reduced the counts to an acceptable level of less than 500 bacteria cm $^{-2}$. The exception in this case was pork sausages where no heat treatment was applied in its production.

Meat hygiene control, primarily of a qualitative nature, is aimed at identifying and eliminating pathogenic organisms. Identification is carried out with purified cultures prepared from factory samples. In the practical commercial situation it is rare that environmental, pH and temperature conditions are optimum for the growth of pathogenic organisms such as *Salmonella* spp., normally poor competitors. Hence Baltzer (1969) maintains that it would be incorrect to produce laboratory cultures under artificially optimum conditions and to extrapolate such a model to the commercial situation, endeavouring to estimate the exact influence of pathogens on the consumer's health. For practical hygiene control purposes, he suggested a number of routine surface sampling methods found to be useful for estimating relatively low bacterial counts on surfaces. High correlations arose between these methods and that is the reality for the meat industry.

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The Danish Meat Research Institute uses methods convenient for testing large numbers of samples which, although possibly less accurate than classical methods, do give reproducible results. Baltzer (1969) contends that as long as the results can be related to practical evidence of quality and are constant, the methods are useful.

In the present study the agar sausage technique of Ten Cate (1965) and Olgaard (1966) was found useful to estimate bacterial counts on processed meat surfaces. Five products from one factory viz. ham, bacon and pork, russian and vienna sausages were included in this survey. An investigation of the possible influence of microbial levels of meat products on shelf life and consumer health should include the role of the production line, since the contribution to contamination by the factory workers, the various utensils as well as the machinery in the factory, all have a significant influence on the level of microbiological acceptibility of the product.

Cured sausages like viennas and russians generally consist of mixtures of pork and beef, salt, sugar, sodium

nitrate and spices (Price & Schweigert, 1971) – presently nitrite is preferred to nitrate. The manufactured products are heated or smoked, and the cured colour develops. The micro-organisms developing on these products are somewhat different to those in fresh pork sausages, which are composed of chopped pork and flavouring agents only (Brandley, Migaki & Taylor, 1966). The latter product receives no heat treatment and therefore by comparison has a somewhat shortened refrigerated shelf life. No previous work on the microbiology of these products in South Africa has been reported to date. The purpose of this study was to determine the influence of the different production steps in a processed meats factory on the microbiology of a number of meat products, which had been produced according to specific manufacturing procedures. The significance of sampling on the production lines was verified by total microbial counts on the final products.

Procedure

Production lines

Agar sausage samples as reported by Ten Cate (1965) and Olgaard (1966) for surface counts cm $^{-2}$, were taken at various stages during the production of five manufactured meat products. Incubation was at 37 ^{o}C for 24 hours for total aerobic mesophilic counts and at 5 ^{o}C for seven days for total aerobic psychrotrophic counts. Finally analyses of variance were executed on transformed point values ($\sqrt{x + 1}$). Where necessary tests for least significant differences (L.S.D.) were carried out (Steel & Torrie, 1960).

(i) Bacon

The bacon production line was monitored as illustrated in Table 1 viz. after curing (2), after smoking (3), after deboning (4) and after pressing (5). At each sampling position 20 gammons, chosen at random, were sampled.

(ii) Sausages

In the case of the pork, russian and vienna sausage production lines 20 pieces each of pork and/or beef were sampled (Table 1). Further monitoring was carried out on the pork sausage production line after filling, directly before packing (3); in the case of the russian sausage line after filling (3) as well as after smoking (4) and for the vienna sausage line directly prior to packaging (3) after the mechanical peeling process.

(iii) Ham

Samples on hams, were taken after deboning (2) and after final trimming (3) (Table 1).

At each sampling position of the above production lines 20 different samples were taken on each product.

Final products (total microbial counts)

Total aerobic counts per gram were made on samples of the final products, in order to determine possible contamination during processing and its influence on the microbial quality of the products when

Table 1

Positions of sampling in the different production lines

Product	Production steps				
	1	2	3	4	5
Bacon	Chilled carcasses	After curing	After smoking	After deboning	After freezing and pressing
Pork sausages	Chilled carcasses	Pork pieces	After filling	–	–
Russian sausages	Chilled carcasses	Pork pieces Beef pieces	After filling	After smoking	–
Vienna sausages	Chilled carcasses	Pork pieces Beef pieces	After cooking and peeling	–	–
Hams	Chilled carcasses	After deboning	After cooking and trimming	–	–

leaving the factory. This was done by means of a "stomaching method" (Sharpe & Jackson, 1972; Emswiler, 1977) on the final product sampled after packaging, directly before distribution. Five samples of each product were examined; 20 grams of each sample was homogenised in 180 mℓ of sterile 0,9 per cent saline solution, with a "Stomacher 400" apparatus. Spread plates of serial dilutions were made on D.H.L. Agar according to Sakazaki (Merck) for determining *Enterobacteriaceae* (24 h/30 °C) and *Pseudomonadaceae* (after an additional 24 h at ambient temperature). The total duplicate aerobic (24 – 48h/30 °C) and *Pseudomonadaceae* (after an additional 24 h at ambient temperature). The total duplicate aerobic (24 – 48h/30 °C) and psychrotrophic counts (7 days/5 °C) were determined by means of spread plates on Plate Count Agar (P.C.A.) (Difco).

Results and Discussion

A survey of the slaughter process at a bacon factory (Nortjé, Visser, Holzapfel & Naudé, 1979) revealed a definite influence of the slaughter line on the contamination of carcasses. It could be expected thus that the production lines at meat factories may also have an influence on the microbial quality of the products. In addition, it is also important to know what the progressive contribution of each step is on the final microbial level observed in the various products.

Table 2 represents the statistical results and Figure 1–5 the mean mesophilic and psychrotrophic bacterial counts cm $^{-2}$ obtained from the point values (Agar sausage technique). Fig. 6 represents the mean aerobic bacterial counts per gram (Stomacher method).

Table 2

The influence of the production line on the microbiology of different products on the line

Analysis of Variance											
Parameter	C.V. %	F-values	L.S.D.*								
			1:2	1:3	1:4	1:5	2:3	2:4	2:5	3:4	3:5	4:5
Bacon (Mes.)	12,58	100,92**	**	NS	**	**	**	**	**	**	**	NS
Bacon (Psych.)	25,99	37,80**	**	*	**	**	**	**	**	**	**	NS
Pork sausages (Mes.)	11,97	49,32**	**	**	–	–	NS	–	–	–	–	–
Pork sausages (Psych.)	13,15	73,80**	**	**	–	–	**	–	–	–	–	–
Russian sausages (Mes.)	21,52	819,0 **	–	–	–	–	–	–	–	**	–	–
Russian sausages (Psych.)	10,30	895,38**	–	–	–	–	–	–	–	**	–	–
Ham (Mes.)	13,06	44,254*	**	**	–	–	**	–	–	–	–	–
Ham (Psych.)	23,56	69,22**	**	**	–	–	**	–	–	–	–	–

NS Not statistically significant
* P < 0,05
** P < 0,01
– Not applicable
*1–5: – See Table 1

Bacon

After 24 hours of chilling (1) the carcasses had a relatively low count of less than 100 bacteria cm $^{-2}$ (Fig. 1) (Nortjé *et al*, 1979). The differences between most production steps were highly significant (P <0,01) for both mesophilic as well as psychrotrophic counts (Tables 1 & 2). After curing and maturing (2) for approximately 19 to 20 days at 5 °C, the counts increased to 500 $^{-2}$ and nearly 1000 cm $^{-2}$ for mesophiles and psychrotrophs (P <0,01) respectively. The higher increase in psychrotrophic counts could be due to the low temperatures in the curing cellars. During smoking (3) both counts decreased to less than 100 bacteria cm $^{-2}$ which was a significant decrease after the curing process (P <0,01).

During the next production step of deboning (4), handling procedures and general hygiene may have been responsible for the increase in microbial counts (P <0,01). The "infinite" counts as specified by Olgaard (1966), (i.e. > 10^4) obtained by the agar sausage technique after deboning, remained at that level when monitored after the product had been frozen for 24 hours and then pressed (5) (P > 0,05). Bacon had a relatively low count in the final product form, as illustrated in the histogram (Fig. 6). All the counts for bacon were within an acceptable range, below 10^6 (Nottingham, 1971; Hobbs, 1967; Dempster, 1977; Reuter, 1972); with those for the *Enterobacteriaceae* even less than 100 bacteria per gram. The influence of the heat treatment during smoking could be the reason for the low counts and therefore a more extended shelf life could be expected. The lower counts obtained by the Stomaching

method, as compared to the agar sausage technique, could be due to the fact that the surface area used for impression counts, loses its identity during the slicing process which also has a dilution effect on bacterial numbers.

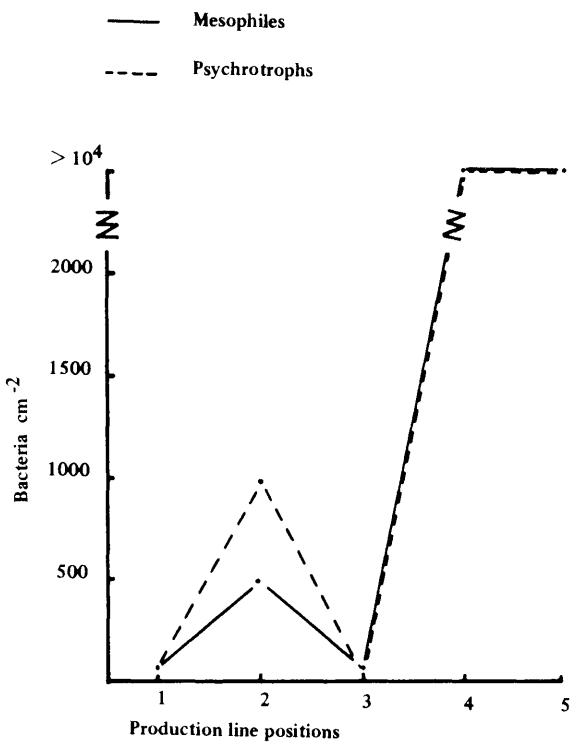

Fig. 1 Mean aerobic bacterial counts on bacon at different positions along the production line

Pork sausages

Differences in bacterial counts between production steps were also highly significant in this case for mesophilic as well as psychrotrophic counts (Tables 1 & 2; Fig. 2). The psychrotrophic count for pork pieces (2), was much higher than the mesophilic count. This could have been caused by the influence of the temperature in the sausage processing room (approximately 10 °C). The final impression counts of pork sausages obtained directly before packaging (3), were higher than those found on all the other products examined, except bacon. The high final count could be due to the absence of heat treatment in the processing of this product. During mincing and filling procedures there may have been a slight increase in temperature, possibly being caused by friction. This could have favoured the increase of mesophiles, therefore leading to the higher counts in this group before packaging. Most of the counts (per gram) for pork sausages were higher (Fig. 6) than those in the other final products, but still less than 10^6. Pork sausage counts were determined 24 hours after freezing. Of the organisms monitored, the *Pseudomonadaceae* and psychrotrophs had the highest counts, ($9{,}8 \times 10^5$ and $6{,}0 \times 10^5$ bacteria per gram respectively) and could therefore shorten shelf life.

A relatively short shelf life for this product was indeed experienced at the factory under discussion with bacon and vienna sausages, pork sausages had relatively low counts of enterobacteria, especially when it is taken into account that this is a raw product.

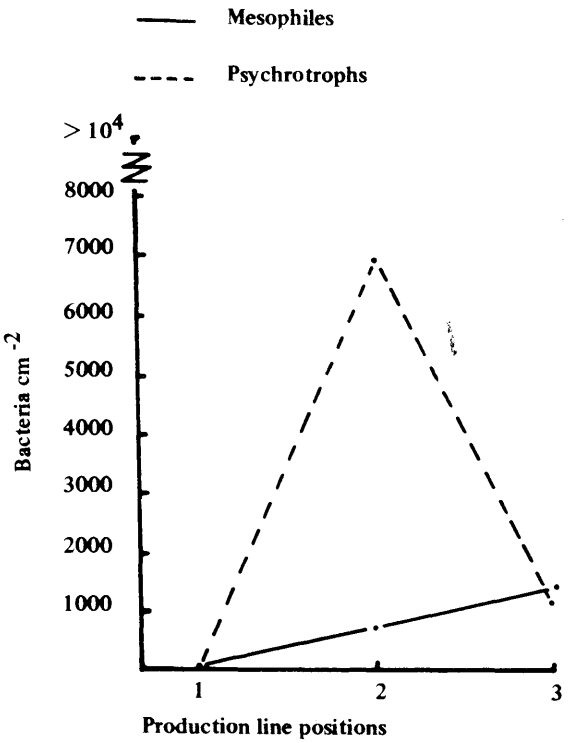

Fig. 2 Mean aerobic bacterial counts on pork sausages at different positions along the production line

Russian sausages

Statistical analyses of the aerobic mesophilic and psychrotrophic counts obtained from the russian sausage production lines are given and the mean counts are illustrated in Tables 1, 2 and Figure 3, respectively.

The cutting of pork pieces for production of this product resulted in a rise in the bacterial count. Numbers of psychrotrophs and mesophiles increased to 6800 bacteria and 500 cm^{-2} respectively. The difference in counts could be caused by the sausage room temperature, as previously stated, which favours the growth of psychrotrophs more than that of mesophiles. Although beef pieces with a very high initial count were added, the final impression counts were less than 50 bacteria cm^{-2} which were significantly lower than those observed after filling ($P < 0{,}01$). This could be the result of the specific heat treatment applied to this product. The russian sausages were thoroughly smoked for about $1\frac{1}{2}$ to 2 h at 50 °C. The counts of the four microbial groups monitored in the product directly before distribution, were relatively low and, as illustrated in the histogram (Fig. 6), never exceeded 10^6 bacteria per gram (Nottingham, 1971; Hobbs, 1967; Dempster, 1977; Reuter, 1972). However, the presence of the relatively high

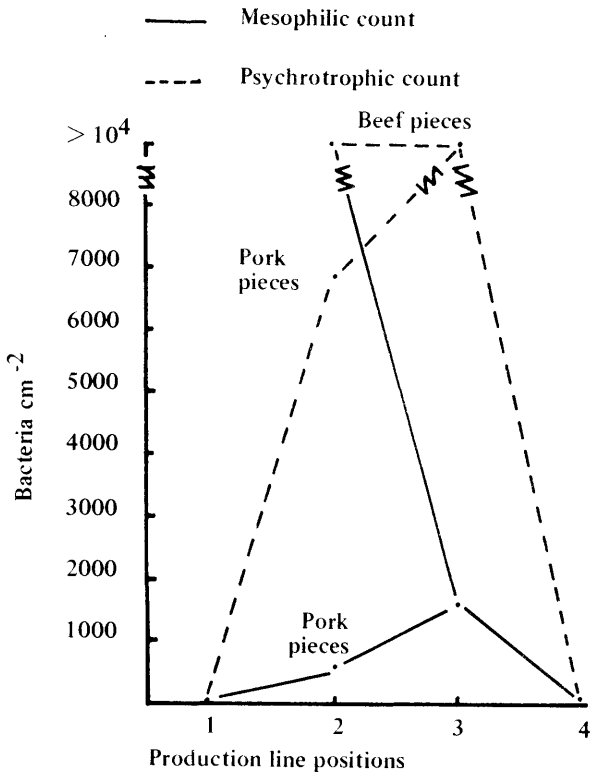

Fig. 3 Mean aerobic bacterial counts on russian sausages at different positions along the production line

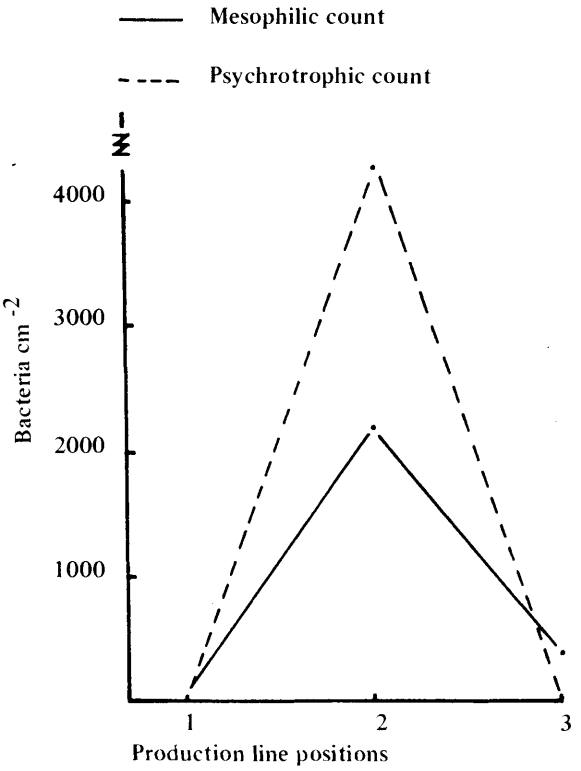

Fig. 5 Mean aerobic bacterial counts on hams at different positions along the production line

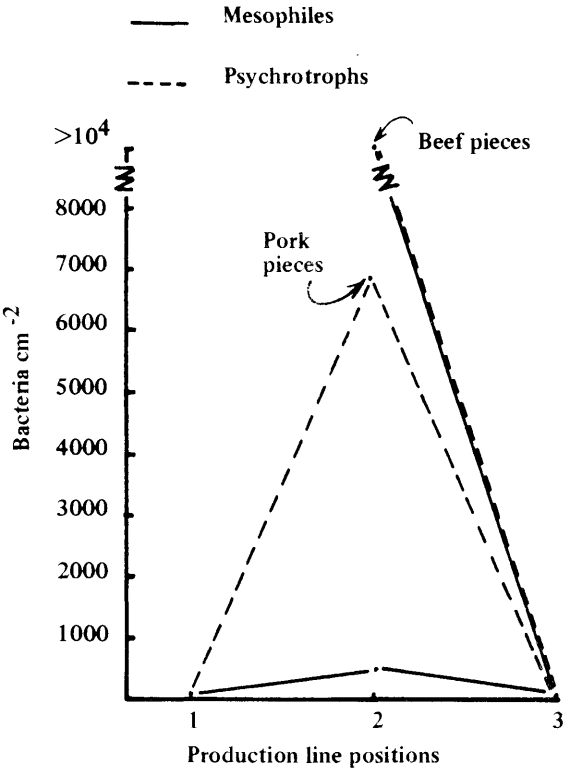

Fig. 4 Mean aerobic bacterial counts on vienna sausages at different positions along the production line

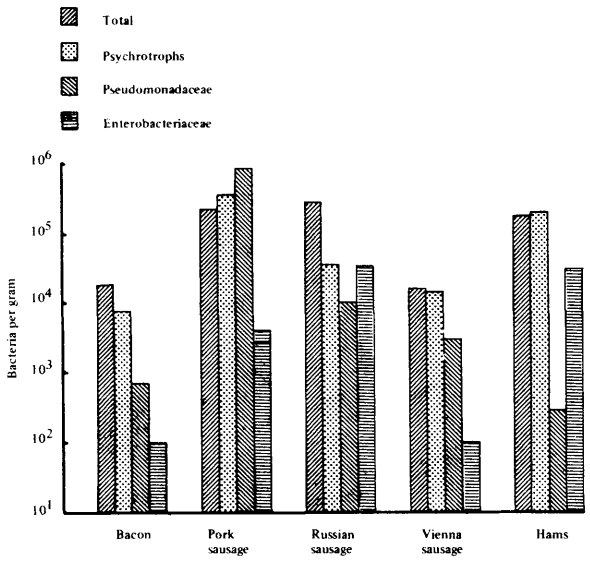

Fig. 6 Mean aerobic bacterial counts per gram on five different products

numbers of enterobacteria in russian sausages in comparison to the other products, could suggest recontamination possibly as a result of insufficient hygienic processing procedures.

Vienna Sausages

Counts obtained from the vienna sausage production line are illustrated in Fig. 4. The pork and beef pieces made a similar contribution to the counts of this product as was the case for russian sausages. The heat treatment (cooking for 30 minutes at 68 to 70 °C) applied to this product, as well as the mechanical peeling process could be responsible for the low counts observed after the peeling process (3). Superficial contamination due to handling was most probably removed by the latter process. The counts on the final product therefore were relatively low when compared to the other sausage types (Fig. 6).

Hams

A significant increase ($P < 0,01$) in counts on hams was determined after deboning (Fig. 5, Tables 1 & 2). This was most probably the result of contamination by factors such as handling and equipment. After cooking the count decreased significantly ($P < 0,01$) to an acceptable level of 500 bacteria cm^{-2} according to Danish standards (Hobbs, 1967). Cooking was performed at 60 °C for approximately 2-3 hours. The duration depends on the time needed to reach an internal temperature of 50 °C. The histogram (Fig. 6) shows that the numbers of psychrotrophs and total bacteria were equally high for this product; which was also found for pork sausages. During ham trimming (after cooking) a certain amount of handling took place and this could have been responsible for the relatively high counts of this cooked product. The high counts of enterobacteria as in the case of russian sausages also reflects recontamination, but in this case is probably due to insufficient hygienic control procedures.

Conclusions

The bacterial counts cm^{-2} on the production lines obtained by means of the agar sausage technique, as well as those per gram obtained by means of the stomaching method on final products, are in correspondence with acceptable counts, given by different research workers (Nottingham, 1971; Hobbs, 1967; Dempster, 1977; Reuter, 1972). However, if general uniform microbiological standards and applicable methods were available, a more precise evaluation could have been made. This again stresses the need for internationally accepted microbial guidelines for the meat industry (Nortje *et al.*, 1979.

A few recommendations can be made which could improve the hygienic conditions and thereby lengthen the shelf life of the final products. In the case of bacon production line, more strict control and supervision at the deboning table could improve the situation, hence lower initial counts on gammons before slicing could be achieved. In the case of vienna and russian sausages, the microbial quality of the product could be improved by using beef with a lower initial bacterial count. Surkiewicz, Johnston, Elliot and Simmonds (1972) stated that freezing would prevent bacterial growth and extend shelf life, but rapid chilling, proper management and clean condiments were essential in retaining the quality of pork sausages during frozen storage. By improving the conditions mentioned above, the quality of the pork sausages which had received no smoking or heat treatment, could be improved likewise. As far as hams are concerned, the situation could be further improved by applying more stringent hygienic practices during trimming of the product.

In the present study the effectiveness or not of hygienic control measures was illustrated in a number of ways. Processes such as curing, smoking, freezing, cooking and peeling are inter alia aimed at preservation, hence a longer shelf life of the product. In the case of all the products, with the exception of pork sausages, one or more of the above processes were applied during processing. In certain cases however it was found that handling which occurred during further preparation of the product prior to packaging, resulted in an increase in microbial counts.

It could therefore be concluded that in order to ensure a high hygienic quality as well as a long shelf life, the accepted microbial control measures of the product should always be combined with strict personnel and factory hygiene control.

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