SSP: MEAT PRODUCTS WITH MINIMAL NITRITE ADDITION, STORABLE WITHOUT REFRIGERATION

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INTRODUCTION

It has been proposed in the Federal Republic of Germany to lower the sodium nitrite content of the nitrite curing salt from at present 0.5 - 0.6 per cent to 0.4 - 0.5 per cent. To the various meat products of this country, depending on the different salt addition, hitherto 90 - 150 ppm nitrite are added, with the new curing salt the addition will be reduced to 75 - 125 ppm. To secure the microbial stability of meat products with the reduced nitrite addition adequate temperatures for their heating and storage have been recommended (LÜCKE et al., 1979).

With an increased awareness of the need for energy preservation also in food processing and storage (LEISTNER, 1980), it will become a challenge for microbiologists and technologists to develop meat products which are storable without refrigeration; even if only a minimal amount of nitrite has been added. In such products the added nitrite should not be essential for preservation, but only for colour and flavour formation in the products, and for the latter purposes an addition of 30 - 50 ppm is sufficient (WIRTH, 1976; LEISTNER, 1979). According to the hurdle concept (LEISTNER, 1977) in a food the parameters or hurdles which secure microbial stability are more or less interchangeable. Therefore, energy consuming hurdles, such as heating and chilling, could be replaced at least partially by less energy consuming hurdles, such as a_w, pH and Eh. The hurdles concept is the basis for a line of meat products, which could be called SSP.

Shelf stable products (SSP) are pasteurized foods which are storable without refrigeration. Meat products based on the SSP concept (LEISTNER et al., 1970; LEISTNER et al., 1979) are mildly heated in hermetically sealed containers to a sufficient extent to inactivate all but sporulated micro-organisms. Due to the sealed container (can, glass jar, pouch, casing etc.) a recontamination of the food with organisms after the heating process is avoided. Therefore, for SSP only spores of the genera Bacillus and Clostridium are relevant. However, in SSP adjusted to a sufficiently low a_w with salts, sugars and powdery additives (milk powder, soja protein, freeze-dried meat) or by the removal of water, growth of bacilli and clostridia, and therefore spoilage or food poisoning, does not occur. This also is true if only a minimal amount of nitrite is added and the products are stored without refrigeration.

In a preceding contribtuion (LEISTNER et al., 1979) two types of SSP meats have been described. Both are traditional products in which the a_w has been adjusted empirically. One of them represents genuine Italian Mortadella, the a_w of which is adjusted by the formula (addition of 3 % salt, 1 % sugar and e.g. 3 % milk powder). The other product is dried Bologna type sausage (i.e. German Brühdauerwurst), the a_w of which is adjusted by a mild drying process (3 weeks at 5 °C or 2 weeks at 10 °C) of the heated product. In both products the a_w is generally adjusted below 0.950.

We investigated the microbial stability of these SSP. Since vegetative organisms in these products should be inactivated by the heating process, decisive for their stability are bacilli and clostridia; especially a_w-tolerant strains. In the present study representatives of the genus Clostridium which are of particular interest with respect to spoilage and food poisoning, and strains of the genus Bacillus which are known to be extraordinary a_w-tolerant were used for inoculation of SSP.

MATERIALS AND METHODS

Products: The formulas of the investigated Mortadella were derived from genuine Italian Mortadella and are listed in Table 1. The formula 1 is an ordinary Bologna type product with a high a_w and served as control. In formula 2 the a_w was adjusted with humectans (3 % salt and 1 % sugar) and the addition of 4 % soja protein. Instead of soja protein in formula 3 skimmed milk powder (5 %) and in formula 4 freeze-dried beef (10 %) were added. The latter was prepared according to POTTHAST et al. (1978). For partial removal of water, the meat for the formulas 2 - 4 was dried 3 days at 4 °C. The pork fat was added to the sausage mix in cubes (8 - 10 mm), as it is usual for Italian Mortadella. With nitrit curing salt 100 ppm nitrite were added to formula 1, however, only 50 ppm nitrite to formulas 2 - 4. After inoculation the sausage mix was filled in casings (90 mm caliber) which are not penetrated by water vapour (NALO Top, Fa. KALLE, West-Germany). The sausages, with a weight of about 1000 g each, were heated with steam to an internal temperature of 75 °C. The products were stored for at least 60 days at 25 °C.

For Brühdauerwurst (dried Bologna type sausage) the following formula was used: 15 % basic mix (85 % beef and 15 % water), 65 % pork, 20 % pork fat, 1 % nitrite curing salt (i.e. 50 ppm nitrite addition), 1,2 % sodium chlorde, 0.5 % spices and 0.03 % sodium ascorbate. After inoculation the sausages were filled in casings (75 mm caliber) which are penetrated by water vapour (Faserdarm, Fa. KALLE, West-Germany). Then they were lightly smoked and heated in steam to an internal temperature of 75 °C. The weight lost during heating was about 4.5 %. Then the sausages were dried at relative humidities from 90 decreasing to 80 %, either 3 weeks at 5 °C or 2 weeks at 10 °C, to an a_w of 0.950. During drying the sausage lost about 25 % of their weight. The control sausages which were not dried and 50 % of the sausages which had been dried were vacuum packaged befor storage, in order to avoid a decrease in a_w during storage. All sausages were stored at 25 °C and 80 % relative humidity for at least 60 days.

Table 1: Formulas for Mortadella type sausages

Ingredients / formulas	Addition in per cent			
	1	2	3	4
Pork	10	40	40	40
Beef	45	31	30	25
Pork fat	25	25	25	25
Water (ice)	20	0	0	0
Milk powder	0	0	5	0
Soja protein	0	4	0	0
Freeze-dried meat	0	0	0	10
Nitrit curing salt	2	1	1	1
Sodium chloride	0	2	2	2
Sugar	0	1	1	1
Spices	0,5	0.5	0.5	0.5
Polyphosphate	0.3	0.3	0.3	0.3
Sodium ascorbate	0.03	0.03	0.03	0.03
A_w	0.977	0.956	0.950	0.936

Microorganisms: The products were inoculated with spores of the genera Clostridium and Bacillus. About 10^5 spores per gram sausage mix were added; the heated products contained 10^3 - 10^5 spores per gram. Twelve experiments were conducted, in each experiment one organism was tested, which in most cases was added to the sausages as a pool of several strains of the tested organism. For the inoculation of Mortadella the following pools were used: C. botulinum type A, C. botulinum type B, C. sporogenes/PA 3679, B. cereus, B. licheniformis, B. polymyxa, B. subtilis (one strain which grows in laboratory media at a_w 0.90; obtained from Dr. J. H. B. CHRISTIAN, Australia) and Bacillus sp. (six strains which partially grow in laboratory media at 0.90 - 0.86; obtained from Dr. B. C. FLETCHER, Unilever Research, U.K.). The Brühdauerwurst was inoculated with C. sporogenes/PA 3679, B. cereus, B. subtilis (CHRISTIAN-strain) and Bacillus sp. (FLETCHER-strains). After the heating process as well as several times during the storage period the number of clostridia in the sausages was counted with SPS-Agar (MERCK) and the number of bacilli with Standard I-Nähragar (MERCK).

Furthermore, Brühdauerwurst was inoculated with a pool of Streptococcus faecium and S. faecalis (3.4 x 10^5/g), with the intention to verify, whether an internal temperature of 75 °C is sufficient to inactivate heat resistant vegetative organisms in SSP. Brühdauerwurst which oposite to Mortadella has a similar a_w on the surface as in the interior of the products was also inoculated on the casing with different moulds (representatives of the genera Aspergillus and Penicillium) in order to test whether mould growth is possible on the surface of this SSP.

RESULTS AND DISCUSSION

In the investigated SSP (Mortadella and Brühdauerwurst) the Bacillus strains tested did not multiply at an $a_w \leq 0.960$. However, to inhibit the genus Clostridium, including C. botulinum, an a_w of ≤ 0.950 must be secured. In the Tables 2 - 6 data of five experiments are shown which illustrate these findings.

In detail the following results were obtained: SSP of the Mortadella and Brühdauerwurst type proved microbiologically stable at 25 °C for at least 60 days (some products were incubated up to 180 days), if the a_w was adjusted ≤ 0.950. To these products only 50 ppm nitrite has been added. Apparently not the type of the powdery additives used (milk powder, soja protein or freeze-dried meat) was decisive for the achieved stability, but the a_w to which the products were adjusted. In Mortadella bacilli (B. cereus, B. licheniformis, B. subtilis and a_w-tolerant Bacillus sp.) did not even multiply if the a_w of the sausage was 0.976. Probably the relatively low redox potential in Mortadella contributes to the inhibition of bacilli in this product. B. polymyxa apparently tolerates a lower a_w than most other bacilli, and therefore has a better chance in Mortadella. The casings of Brühdauerwurst are not only penetrated by water vapour but also by oxygen. This might be the reason that in Brühdauerwurst with high a_w (0.976) not only clostridia multiplied but also bacilli (B. cereus, B. subtilis and a_w-tolerant Bacillus sp.).

An internal temperature of 75 °C proved sufficient to inactivate heat resistant none-sporeforming organisms (S. faecium and S. faecalis) in Brühdauerwurst. The surface a_w of Mortadella corresponds to the relative humidity of the surrounding air, and since this is generally not above 60 % no growth of microorganisms occurs on the surface of this product. Since the casing of Brühdauerwurst is penetrated by water vapour, the surface a_w is as high as in the interior of the product. Therefore, inoculated Brühdauerwurst supported mould growth. These undesirable moulds were not inhibited by the smoke applied

or by vacuum packaging of the sausages. However, no growth of microorganisms occured on the products dipped in a 20 per cent potassium sorbate solution. In West Germany so far a potassium sorbate dip is only allowed for fermented sausages and raw hams, however, not for Bologna type sausages.

The bacterial spore inoculum used for the SSP experiments conducted was rather high, because 10^3 - 10^5 spores per gram survived the heating process. In studies about the inhibitory effect of nitrite in meats usually only 10^2 - 10^3 spores are used as inoculum. In spite of the high challenge (inoculum) SSP meats with a proper a_w proved stabil, also at prolonged incubation at 25 °C. Therefore, apparently it is more feasible to stabilize meat products by a_w reduction than by nitrite addition.

There is general agreement that spores of Bacillaceae may initiate germination at a_w levels appreciably lower than those which will permit vegetative cell growth to occur. This phenomenon has been discussed by LEISTNER et al. (1980). That spores of bacteria germinate in SSP below the critical a_w for growth is significant, since the number of surviving spores in such products could decrease during storage; as has been already observed by LEISTNER et al. (1970). In the present study in Mortadella as well as in Brühdauerwurst the number of surviving organisms declined during the storage of stable products, and thus the microbial status of these products improved with storage.

Probably the stability of SSP meats could also be achieved by an adjustment of the pH. Traditional products of this type are brawns and Gelderse Rookworst. The latter product is common in the Netherland, and also is exported from this country. Gelderse Rookworst is a Bologna type sausage of which the pH is adjusted by the addition of Glucono-delta-lacton (Gdl). The product is vacuum packaged and reheated in the pouch. Gelderse Rookworst with a low pH does not need refrigeration. At present we study the microbial stability of Rookworst to which 0.8 % Gdl has been added, resulting in a pH of 5.2 - 5.4. Such a pH is still acceptable in Bologna type sausages from the sensoric point of view and also with respect to the binding of water in the product (LEISTNER, 1980).

CONCLUSION

SSP meats offer the following advantages: 1. Mild heat treatment, which improves the sensoric and nutritional properties (e.g. preservation of vitamines) of the products and saves energy. 2. No refrigeration required, this is simplifying the distribution of the products and saves much energy during storage. 3. Little addition of nitrite ($\leq$ 50 ppm), since nitrite is only necessary for the colour and flavour of the products, but not for their preservation. Considering these advantages SSP might become meat products with future.

Table 2: Mortadella inoculated with Clostridium botulinum type B (pool of 4 proteolytic strains)

Additives for lowering a_w	Nitrite addition ppm	A_w at beginning of storage	C. botulinum (x 100)/g during days at 25 °C					First spoilage after days	Botulinum toxin present*
			0	15	30	60	150		
Control	100	0.977	30	**	**	**	**	11	3/3
Milk powder 3 %	50	0.956	60	30	3	**	**	36	3/1
Soja protein 4 %	50	0.956	50	10	1	**	**	42	3/1
Freeze-dried meat 10 %	50	0.950	50	30	10	2	1	none	3/0

* Number of tested/positive samples ** Not investigated

Table 3: Mortadella inoculated with Clostridium sporogenes/PA 3679 (pool of 5 strains)

Additives for lowering a_w	Nitrite addition ppm	A_w at beginning of storage	C. sporogenes (x 1000) per gram during storage (days) at 25 °C									
			0	7	14	21	28	40	60	100	150	180
Control	100	0.976	78	1	100	* 16th	**	**	**	**	**	**
Soja protein 4 %	50	0.956	100	10	3	31	800	* 40th	**	**	**	**
Milk powder 5 %	50	0.950	78	10	0.1	0.1	0.1	1	0.01	0.1	0.1	0.1
Freeze-dried meat 10 %	50	0.936	100	10	3	3	1	0.2	0.01	**	**	**

* Day of first spoilage ** Not investigated

Table 4: Mortadella inoculated with a_w-tolerante Bacillus sp. (pool of 6 FLETCHER-strains)

Additives for lowering a_w	Nitrite addition ppm	A_w at beginning of storage	Bacillus sp. (x 1000) per gram during storage (days) at 25 °C									
			0	7	14	21	28	40	60	100	150	180
Control	100	0.976	140	100	130	780	110	85	200	16	*	*
Soja protein 4 %	50	0.956	140	200	98	130	100	800	1	91	18	88
Milk powder 5 %	50	0.950	100	98	1200	800	160	130	53	70	*	77
Freeze-dried meat 10 %	50	0.936	140	140	200	800	220	200	12	120	160	140

* Not investigated

Table 5: Brühdauerwurst inoculated with Clostridium sporogenes/PA 3679 (pool of 5 strains)

Drying temperature	Nitrite addition ppm	A_w at beginning/end of storage	C. sporogenes (x 1000) per gram during storage (days) at 25 °C						
			0	7	14	21	28	40	60
Not dried	50	0.974 *	30	1	** 10th	***	***	***	***
5 °C	50	0.950 *	30	29	23	28	20	8	3
	50	0.95/0.85	30	29	23	28	20	22	2
10 °C	50	0.950 *	30	28	28	11	10	6	3
	50	0.95/0.85	30	28	28	25	20	8	4

* Sausages were stored vacuum packaged ** Day of spoilage *** Not investigated

Table 6: Brühdauerwurst inoculated with a_w-tolerant Bacillus sp. (pool of 6 FLETCHER-strains)

Drying temperature	Nitrite addition ppm	A_w at beginning/end of storage	Bacillus sp. (x 1000) per gram during storage (days) at 25 °C						
			0	7	14	21	28	40	60
Not dried	50	0.974*	90	80	60	42	53	** 40th	***
5 °C	50	0.950*	90	***	***	74	87	63	60
	50	0.95/0.85	90	***	***	74	37	60	53
10 °C	50	0.950*	90	***	130	70	64	62	30
	50	0.95/0.85	90	***	130	70	91	60	41

* Sausage were stored vacuum packaged ** Day of spoilage *** Not investigated

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