The Applications of High Frequency Field in Food Industry

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Since food production lags far behind the growth in world population it is a fundamental aspiration all over the world to increase food supplies.

The most urgent task is to process the available raw materials with the least possible loss of quality and quantity.

As it is known water is a basic and most important component of the raw materials of animal and vegetable origin, used in the food industry. Water molecules, either free or bound by various amounts of energy, form an essential part of living material, of cells and play an important role in their microstructure and in the formation of their physicochemical properties. Biological procedures both in animals and in plants, in their primary and secondary metabolism, take place mainly in aqueous medium and this aqueous medium is of decisive importance also in the processing of these raw materials.

Great effort is made to eliminate or inhibit the undesirable native, extrenous physical, biochemical or microbiological processes, affecting unfavourably the product during harvesting, storage, preceding processing, and processing, by refrigeration, heat treatment, or reducing the moisture content below a certain level, or by inhibiting the activity of catalytic substances. Thus one of the most important methods of food processing is heating which has a basic function in preservation by pasteurization or sterilization, or on the other hand, in preservation by dehydration.

It is well known that the heat conductivity of materials of animal or vegetable origin is very low therefore heat treatment is inevitably accompanied by sudden drop of temperature towards the inside of the material treated.

If it is tried to control the temperature differences the time, needed to heat up the material is substantially increased, however this is, in most cases insupportable because it assists processes unfavourably affecting the quality of the product.

If high temperatures are applied the time needed for raising the temperature is reduced, this causes however the overheating of certain sections of the processed material impairing thereby its quality. The customary heat treatments are always accompanied by temperature gradients, and temperature gradients cause the accumulation of the moisture content in the colder parts of the material treated. This of thermo-diffusional character phenomenon not only increases uneven moisture distribution in the material, but substantially hinders moisture diffusion towards the evaporating surface.

A method theoretically suitable to eliminate all the above enumerated difficulties seems to be, the application of high frequency field. Research work on the application of high frequency energy in the field of food processing has been going on since 1954 in Hungary.

I wish to discuss here only the subjects where this technique underwent not only laboratory scale trial but was studied either in pilot plant or large scale industrial production. The main fields of the food industry where the application of high frequency energy seems practical are the following:

A. Heating, dehydrating, roasting,
B. Preservation by pasteurization, sterilization,
C. Blanching, cooking, baking,
D. Thawing of frozen goods,
E. Control of insect infestation by killing them.

A. To demonstrate the utilization of high frequency energy for heating I am showing the flow diagramme of the dielectric fat rendering process and equipment worked out in the Central Food Research Institute, Budapest (Fig. 1.) In this process advantages of homogenous energy input by high frequency field and of close controllability are utilized in rendering fat of low thermal conductivity. Rendering in a high frequency field takes about one tenth of the time required for traditional fat rendering. Due to close controllability, the rendering temperature may be set at 58 °C and thus, the fibre protein is not denaturalized. By eliminating the temperature gradient the continuous rendering process produces 2 phases, lard itself and fatty, not denaturalized

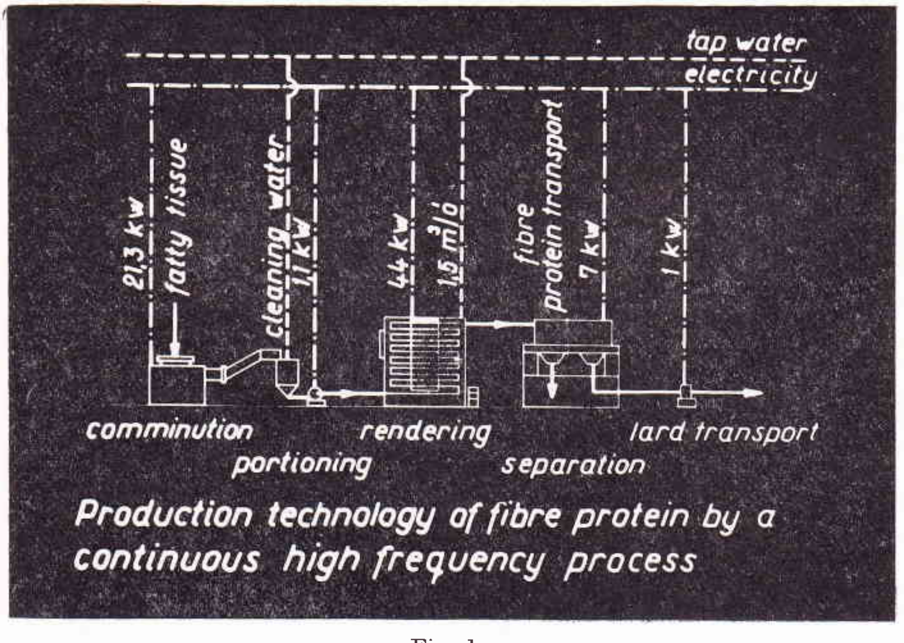

Fig. 1.

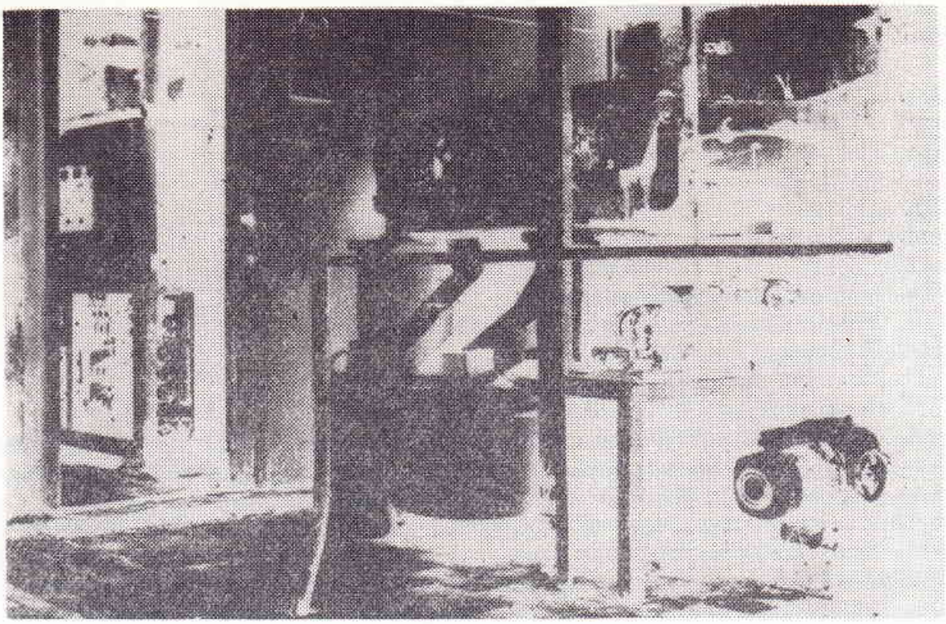

Fig. 2.

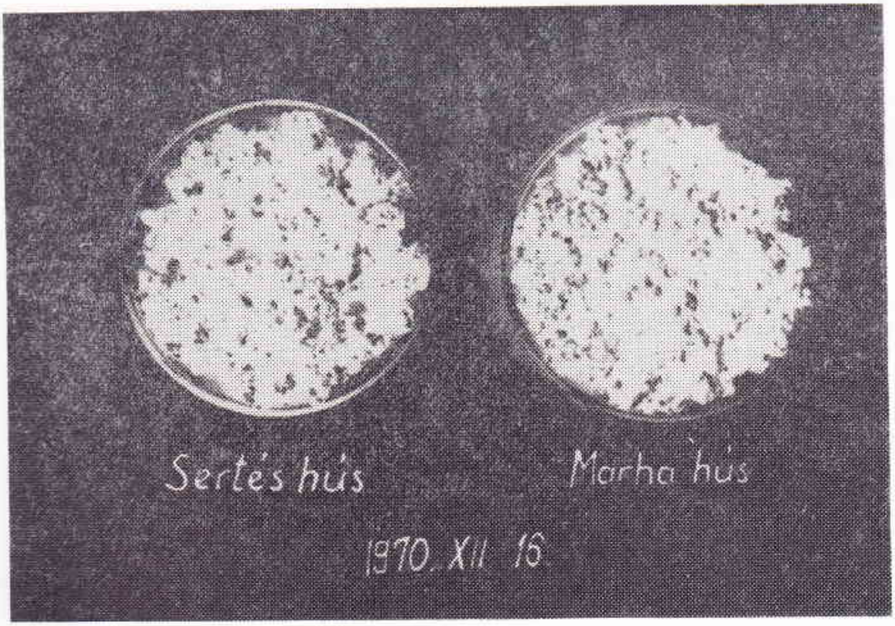

Fig. 3.

fibre protein, thus all disadvantages of traditional rendering and "wet rendering" are eliminated.

Drying curves of materials of high moisture content and of biological origin show that 80—85% of the moisture content is evaporated during 50—60% of the total drying period. To achieve an air-dry product the last phase of dehydration takes a relatively long time and requires inproportionately high energy input. To remove the moisture content, falling under the protracted section of the drying curve, high frequency energy seems suitable. The combination of traditional and high frequency drying reduces the specific energy consumption of the drying process and substantially increases the capacity of the drying equipment.

Hop, tobacco and Italian paste drying experiments, carried out partly in laboratory, partly on industrial scale resulted in about 20—30% reduction of the specific energy consumption and in an about 25—50% increase of the capacity of the equipment. At the same time the investment costs of the high frequency field required to increase capacity to that extent amount to about 10—25%, of the costs, of increasing the capacity in the traditional way.

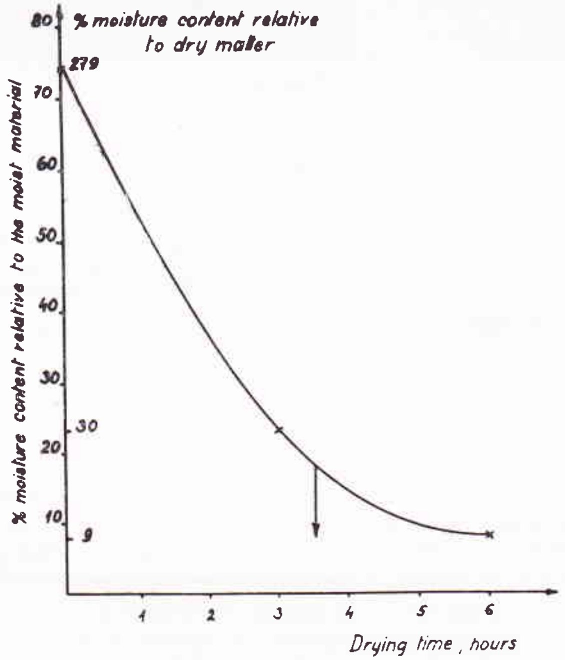

Fig. 4.

The drying curve of traditional hop-drying and the curve showing the time reduction achieved by final drying with high frequency energy are shown in Fig. 4. A schematic diagramme of the pilot plant is shown in Fig. 5.

The products obtained by combined drying technique have a more favourable microstructure and shelf life than the products of traditional drying. For instance the cooking time of dried hop obtained by the combined method is

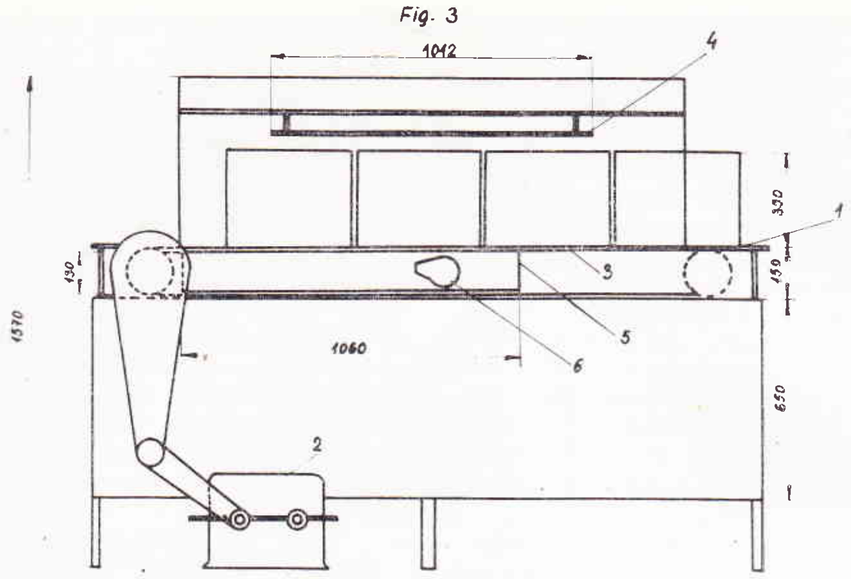

Fig. 5.

Average values belonging to various boiling times

	Boiling time	Bitter value mg/l	AL number
Average values belonging to hops dryed by high frequency	15'	29,6	70,2
	20'	30,6	72,1
	30'	32,6	66,0
	50'	39,5	70,0
	90'	38,2	70,0
Average values belonging to hops dryed by conventional method	90'	31,1	69,7

Fig. 6.

about one third of the traditional, and 10—15% more bitter value is obtained (Fig. 6.).

In experiments carried out with sunflower seeds, the peroxide value, titratable acidity of the seeds dried by the combined method did not change during an extended storage period and rancidity was not observed.

The favourable microstructure as achieved by combined drying improves the pressing quality, results in a higher oil yield and permits of the application of higher final pressures. The product is easier to refine.

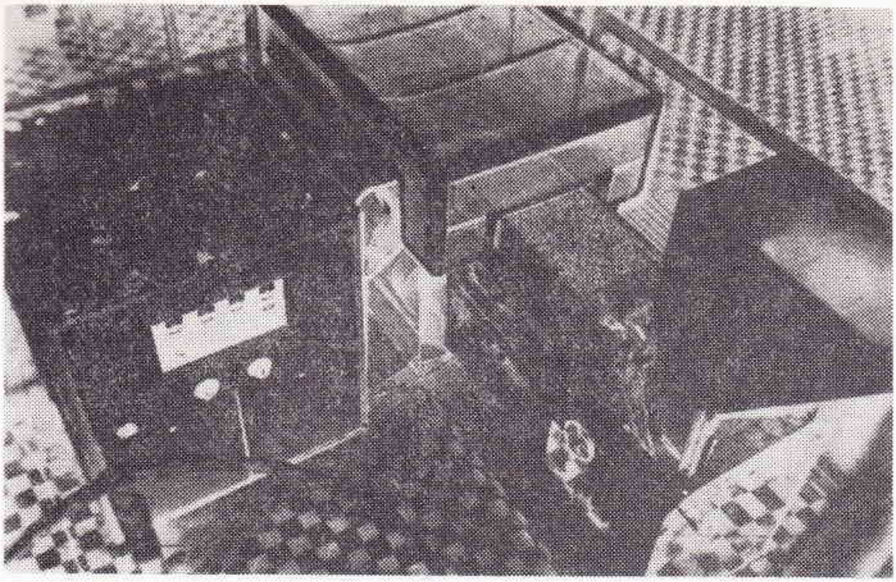

Fig. 7.

The residual oil content in rape seeds given combined drying treatment is about 4—10% less, relative to the oil yield after extraction.

Another example of the utility of high frequency energy in final drying was found with cube sugar. Cube sugar is cut from bars obtained by pressing granulated sugar with the addition of 1—2% water. The moisture content has to be removed after cutting. To reduce the moisture content to 0.20—0.25% in an up-to-date infrared drying tunnel of continuous operation 64.5 kWh are required per ton. According to the results of laboratory experiments this energy requirement can be reduced to one third by the application of a high frequency field.

As an example of roasting that of cocoa beans shell be mentioned. It was proven in industrial experiments that high frequency energy can be utilized for cocoa beans roasting. In a modern equipment, operating a generator of 50 kWh mains load, cocoa beans can be roasted at a rate of 0.3—0.4 tons/h. At the same time, the time requirement is reduced to 25—50% of the traditional. The product is of better quality, roasting loss is reduced and the operations following roasting, husking and cocoa butter pressing are promoted. The costs of increased power requirement is paid back many times over, by the reduction in loss of oil. The industrial equipment is shown in Fig. 7. and the balance of materials in Fig. 8.

B. In the field of preservation and sterilization, experiments are in progress in the our Central Food Research Institute to construct a continuous operation fruit juice pasteurizer. Besides the applicability of plastic packing it would proffer the advantages of rapid heating and cooling..

C. In the field of blanching, cooking and baking, the blanching in plastic pouches of shelled green peas is worth mentioning. Experiments were carried

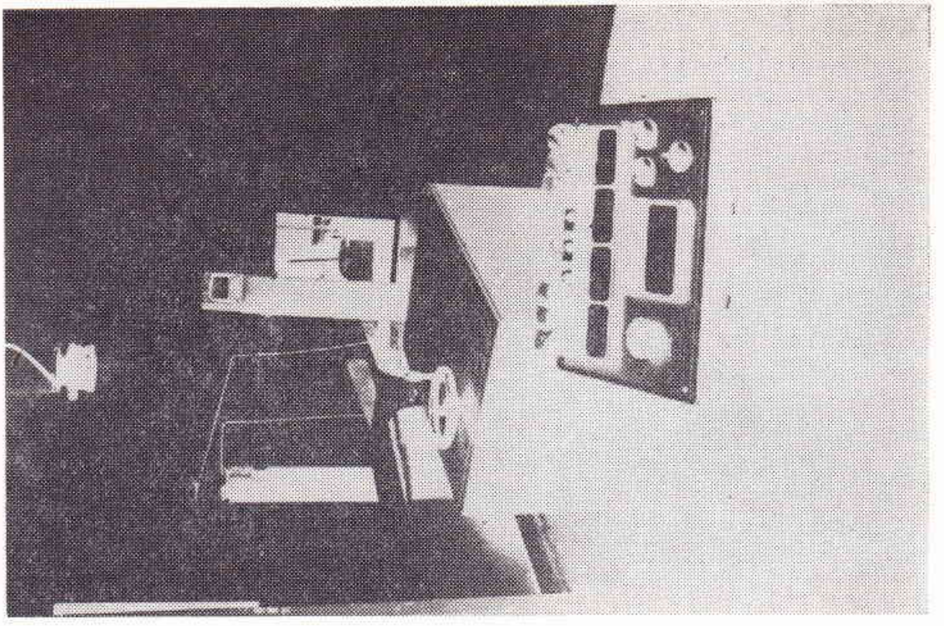

Fig. 8.

out in view of extending temporary storage and results showed that by blanching in pouches provisional storage can be extended by 1—3 days.

As regards the use of high frequency energy in cooking the example of Bologna sausage shall be mentioned. According to experiments carried out in (the our Central Food Research) Institute an excellent product can be made with a cooking and cooling time of only one hour, instead of the traditional 24—48-hour cooking and smoking period, if the traditionally prepared sausage is treated in a high frequency field. As an example of baking in high frequency field I mention the pilot plant equipment developed for the continuous baking of bread in (the our Central Food Research) Institute Fig. 9. The specific volume of breads produced in this equipment is 20% larger than bread made in the traditional way (Fig. 9a). The cross section of bread baked in the high frequency field is even, and if this method is combined with infrared bread-crust forming, or traditional baking to form crust, the time requirement is still only 30—50% of that of the oven-baked bread. Bread baked in this way is not sensitive to differences in the leavening process and flour of poorer quality can also be used. The power requirement is 0.32 kWh/kg product. Traditional baking lines can be complemented with equipment for combined baking.

D. A pilot plant equipment was developed at (the our Central Food Research) Institute for the thawing with high frequency energy of frozen liver and boned meat blocks. As proven in laboratory and industrial experiments a 1.5—2% reduction of loss on thawing can be achieved by drir reduction. The consistency of the thawed product can be adjusted to the requirements of the following operation and is more favourable from the point of view of

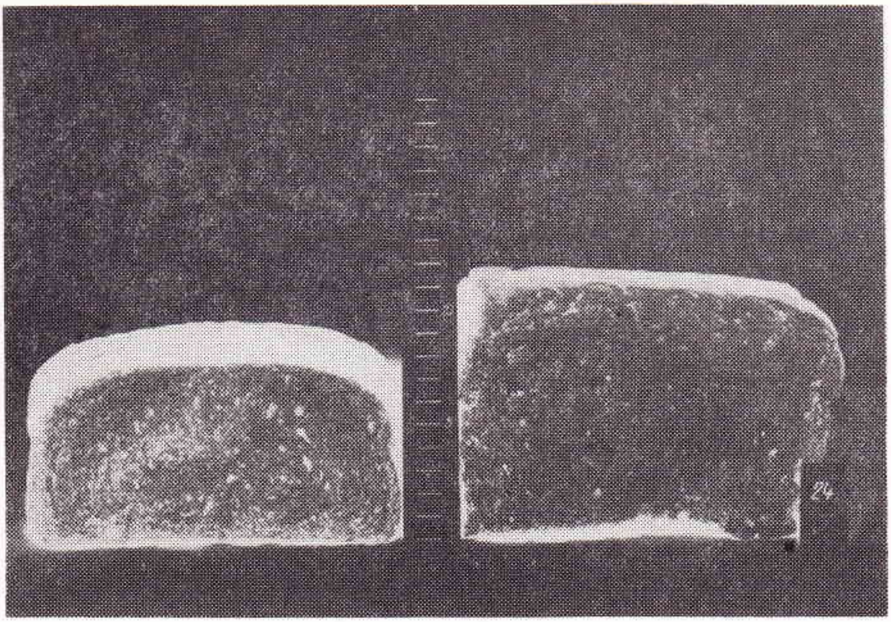

Fig. 9.

both hygiene and economy than the traditional methods. The industrial equipment is illustrated in Fig. 10. and results are given in.

A high frequency thawing method was also worked out for the continuous thawing of liquid egg frozen in cannisters. The loss on thawing was reduced by about 3% and the sanitary quality of the eggs is better than that of traditionally thawed eggs.

A solution was also found for the partial thawing of frozen fish blocks. With high frequency energy input it is possible to brake up the blocks in the temperature range of —1 °C to —1,5 °C. Thus it becomes possible to provide retail shops with household-size frozen fish packs. The energy requirement of this heating process is relatively low, it is 110 kWh/ton. The process is expected to be scaled up for industrial use.

In the following I try to outline the
high frequency and ultrahigh frequency energy input
in European food production and preservation.

The advantages of applying high frequency field in food production and preservation have been known since 1920. Experiments were carried out in almost every branch of the food industries in view of the utilization of high frequency energy. The development of diathermy promoted these investigations. However, technical conditions ripened only after the Second World War to enable the industrial realization of some of these methods. The trend of development was determined by the rapidly advancing microvawe technique in the United States. The output of the high frequency equipment used in the food industries in Europe is estimated to be about 5—6 MW. Ultrahigh frequ-

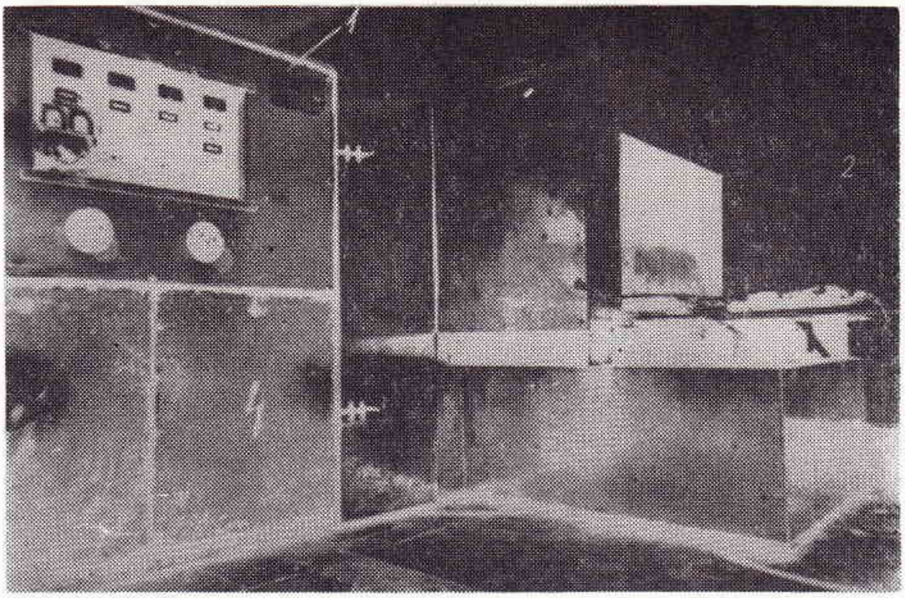

Fig. 10.

ency equipment has been introduced only in recent years and their total output does not exceed 1—2 MW.

A. In the field of heating and dehydrating the application of high frequency energy in the final drying of sugar is worth mentioning. In Sweden it was introduced in 1964. The high frequency drying plant in Arlőv has an output of 1000 KW and operates at 27 Mc. The operation cost is 0.2 cent/kg sugar. In the last 5 years microvawe lines of substantial output have been established in Great Britain for the final drying of potato slices. The experiences of previously in the USA established similar potato drying lines were utilized. The output of the lines is estimated at about 0.8—0.9 MW. The coefficient of efficiency is very good, it is about 70—75%.

The final phase of biscuit baking may also be considered a drying process. According to the information given by the Swiss firm "Reforma" in Italy and other Europian states a great number of continouos biscuit baking equipment is being operated. On the 25 quadrat metre conveyor surface 1 ton of product is manufactured, twice, threetimes the quantity possible to produce by the traditional method. The organoleptic quality of the goods produced by this combined method, and their storage stability is better than that of goods produced in the traditional way.

B. The first pilot plant for high frequency pasteurization of bottled fruit was established in the Sovietunion. An equipment for the pasteurization of beer was developed by Brown Boveri. Heating, requires only 2 minutes as against the 40—60 minutes required by the traditional method. The technique helped to substantially reduce the braking of bottles.

The firm "Reforma" established an equipment for the sterilization of animal feed in Switzerland in 1966. Dry feed is sterilized at 121.1 °C.

C. For high frequency baking, equipment was developed and set up by Reforma (Brown Boveri) and Radyn Ltd in various parts of Europe. The equipment of Brown Boveri bake the products in a vertical radio frequency field and develop the crust with infrared radiation. The Radyn equipments may be attached to ordinary baking lines and apply horizontal field. The increase in capacity related to the length fo the baking line is 50% in the case of both equipments. The volume and storage stability of the product surpasses that baked in the traditional way. The construction of Brown Boveri for the leavening of dough reduces the time requirement to one third.

From the two constructions more than 100 are in operation. The largest one is the final baking plant of about 300 kW output, established in Italy by Radyn. New types of equipment are developed by European firms for the pasteurization of bread, giving 10 kW useful output at 900 or 2450 Mc frequency. It the case of a pasteurization period of 1—2 minutes, the output of these lines is hourly 250 kg bread.

D. For thawing frozen goods the first high frequency industrial unit was installed in the United Kingdom. The output of a conveyor operating with 6 generators of 20 kW useful output each, is 1—1,4 tons/hour. About 10—15 similar equipments for the thawing of fish blocks is in operation.

For the thawing of frozen meat in meat processing plants in Switzerland, equipments permitting of thawing of 0.2—1.0 ton/hour are used. Probably 5—10 similar equipments are used.

In Scotland an equipment operating with a generator of 250 kW useful output and thawing 5 tons/hour frozen meat trimmings for the purpose of animal feed manufacture is used.

Apart from the industrial equipments enumerated many thousends of equipments of lower output (1—2 KW), operating with microwaves are in use all over Europe. These are used mainly in catering establishments for the heating of frozen dishes and prepared foods.

E. For protection against insect infestation two equipments were developed by Brown Boveri in Belgium, they are operating at 15 Mc and 2450 Mc, respectively. The parasites are killed within 20—60 seconds. The average temperature increase in the products treated is 20—40 °C. An equipment of 10 KW useful output operating at 15 Mc is capable of treating 300—500 kg product/hour. The possibilities of utilization of high frequency energy in the field of food production will emerge in the results of the laboratory and pilot plant experiments is progress. However the installation of large scale industrial equipment all over Europe proves the feasibility of this new technique. In the knowledge of the results of research work in laboratory as well as industrial scale investigations the utilization of high frequency energy seems probable in the following fields:

In the blanching of vegetables high frequency and microwave dielectric processes and their combinations with traditional methods of blanching in water or steam. Experiments hitherto carried out showed that processing based solely on high or ultrahigh frequency energy input, or their combinations with traditional methods of blanching were advantageous from the point of view of protecting ascorbic acid and chlorophyll content and helped in the maintenance of the hedonic value.

Thawing of frozen vegetables and fruits for processing purposes or for direct consumption with high frequency energy has the extraordinary advantage of being adjustable to the requirements.

In the field of cooking, pasteurization and sterilization the development of technologies utilizing high or ultrahigh frequency or their combination with traditional methods permits of substantial cutting of the treatment times and of extended storage life.

Greatest possibilities appear in this respect in the field of meat processing. The development of continuos processes for the production of skinless sausages is expected. Further possibilities are envisaged by the application of high-frequency combined with gamma radiation, for instance in the packaging of Vienna sausages under vacuum.

High frequency processes permit of "dry cooking" whereby the 5—15% loss accompanying traditional cooking and the loss of substances of biological value can be eliminated. The first practical application of this principle is continuous liver paste manufacture.

The utilization of high frequency energy in the continuous sterilization or pasteurization of liquid, pulpy or solid foods seems also very promising. Units packed in plastic pouches of low loss factor assembled in pressure resistant cases of similar electrophysical properties, can be heat treated on the conveyor belt, and thus it can be attached to modern continuous operation production lines. The thawing of meat products by high frequency energy is a hygienic precondition of the large scale manufacture of prepared or precooked foods, but soon it will be an inevitable operation in meat processing and canning. Another important field of application is the thawing of frozen dishes in institutional catering.

The introduction of high frequency roasting ensures the accurate control of roasting processes, a substancial improvement of quality, the prevention of overheating and thereby elimination of the deleterious by-products of overheating.

Tab. 1.

	Power density	Time of treat-ment in min.	Final tempe-rature of roasting °C	Meisture content in the bean	Meisture content in the shell	Fat % in the shell	Roasting loss
High frequency roasting	0,55	9	142	2,4	5,0	2,07	3,6
	0,60	8	143	2,2	4,6	2,18	3,5
	0,56	9	145	2,1	4,7	2,11	3,9
	0,52	10	146	2,1	4,3	2,20	4,0
	0,58	8	144	2,3	4,2	2,27	3,3
	0,55	9	146	2,1	3,8	2,05	3,3
	0,53	9	144	2,3	4,1	2,30	3,1
Conventional roasting	—	23,8	147,4	1,78	3,02	5,2	6,1
Raw material	—	—	—	5,1	12,7	1,79	—

Tab. 2. The respective drip losses in frozen liver blocks of varied storage loss, on thawing conventionally or by high frequency treatment

No	Freezing and storage loss as percentage of weight previous to freezing		Drip as percentage of weight previous to thawing			
			H. f.		Conventional	
				Dry matter %		Dry matter %
IV	0,14	$\sigma_0 \pm 0{,}02$	1,28		2,59	
V	0,12	$\sigma_0 \pm 0{,}02$	1,59		2,91	
IX	0,18	$\sigma_0 \pm 0{,}03$	1,32		2,86	
III	1,38	$\sigma_0 \pm 0{,}06$	3,22	18,1	5,60	20.7
X	1,53	$\sigma_0 \pm 0{,}12$	4,26	17,9	6,54	19.3
XI	1,69	$\sigma_0 \pm 0{,}10$	4,62	17,1	7,47	19.6

In the field of drying a 50—100% capacity increase can be expected by the introduction of high frequency techniques in the removal of the final few percentages of moisture. By relatively small investment, the quality of the product, its storage stability can be increased in everyone of the drying technologies: airdrying, vacuum systems, freeze-drying and helps to solve the processing of new products.

The quality of baked products is improved by the application of dielectric baking technology. The new technology, or its application in combination with traditional methods results in products a better storability. New continuous dough processing lines can be complemented by this system, and thereby a substantial increase in capacity and the elimination of production peaks can be achieved.

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Aplikácia vysokofrekvenčnej oblasti v potravinárskom priemysle

Súhrn

Autor sa zaoberá aplikáciou vysokofrekvenčnej energie v potravinárskom priemysle v týchto odboroch: ohrev, dehydratácia, praženie, pasterizácia a sterilizácia, blanšírovanie, varenie, pečenie, rozmrazovanie mrazených tovarov, dezinsekcia obilia. Opisuje výsledky vlastných pokusov pri vytápaní slaniny, sušení chmeľu a pražení kakaových bôbov. Uvádza prehľad a aplikácie vysokofrekvenčných zariadení v priemyslovom meradle v Európe. Záverom navrhuje ďalšie možnosti aplikácie.

Применения высокочастотной области в пищевой промышленности

Выводы

Автор занимается в статье применением высокочастотной энергии в пищевой промышленности в следующих областях: нагрев, дегидратация, обжаривание; пастеризация и стерилизация; бланшпрование, варка, печение, размораживание мороженых товаров; дезинсекция зерновых хлебов. Описывает результаты собственных опытов с вытапливанием сала, сушкой хмеля и обжариванием бобов какао. Дает представление о применении высокочастотных установок в промышленном масштабе в Европе. В заключение он приводит дальнейшие возможности применения.

Application of high-frequency region in food industry

Summary

The author of this article deals with the high-frequency energy application in the food industry in following fields: heating, dehydration, roasting, pasterization, sterilization, blanching, cooking, baking, defreezing of frozen foods; corn-desinfection. The author describes the results of his own experiments with lard-melting, hop-drying, and roasting of cocoa beans. Further gives the survey on application of the high-frequency equipment in European industry.
In conclusion he outlines farther possibilities of application.