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COMPARATIVE EVALUATION OF NUTRITIVE AND SENSORY VALUE OF SELECTED RAW MATERIALS AND DISHES AFTER THERMAL PROCESSING IN A CONVECTION OVEN AND WITH CONVENTIONAL METHODS

Katarzyna Waszkowiak, Krystyna Szymandera – Buszka, Witold Janitz, Danuta Gorecka
Department of Human Nutrition Technology, University of Agriculture, Poznan, Poland

ABSTRACT

In the research the effect of thermal processing in a convection oven on dishes quality was evaluated. The quantitative and qualitative changes of some nutritive values and sensory indices were estimated in comparison with conventional methods of thermal processing. In the study raw materials and dishes of vegetable (sauerkraut and potatoes) and animal origin (cooked and roasted meat, cooked and fried minced meat balls) were investigated. The content of ascorbic acid and neutral detergent fiber (NDF) were used as the nutrition value indices of investigated vegetable dishes. Thiamine and collagen changes in meat dishes and retention of iodine in

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the products (meat balls) with addition of iodized salt were analyzed. All prepared dishes were sensory evaluated with the triangle test.
In the vegetables cooked in a convection oven lower vitamin C losses were observed. There was 20% more vitamin C in sauerkraut and 10% in potatoes.
In vegetables the NDF content depended on the kind of raw material and the method of thermal processing. Growth of the NDF content was beneficially influenced by thermal processing in a convection oven in the case of sauerkraut and by traditional cooking in water in the case of potatoes.
Thermal processing of meat dishes in a convection oven limited the losses of total thiamine content (on average by about 5%). The iodine losses were also limited by using this method: for cooked minced meat balls by about 22% and for fried ones by about 26%. Analysis of changes in total and soluble collagen content during meat cooking indicated lower level of collagen thermohydrolysis for cooking in a convection oven. The differences, however, did not affect sensory evaluation of meat tenderness.
Sensory evaluation indicated that the quality of dishes cooked in a convection oven was preferred to that of the ones prepared by traditional methods.

Key words: convection oven, dietary fiber, ascorbic acid, thiamine, collagen, iodine retention

INTRODUCTION

Heating food products using various heat releasing media, i.e. thermal processing, is one of the most important stages in dishes production technology. The changes taking place during thermal processing can both improve and deteriorate broadly understood dish quality which includes sensoric, microbiological, and nutritive value. The process also causes transformation of raw material components resulting in loosening of plant and animal tissues, increasing digestibility and availability of some components, deactivation or removal of anti-nutrient substances and production of substances determining colour, taste and smell. During thermal processing bacteria and parasites present in raw material are eliminated.

Thermal processing is also responsible for unfavourable changes causing loss of water soluble components, mostly due to leaching, high temperature, oxidation and other transformations related to, among others, the loss of water.

Final dish quality is highly affected by a selection of the method and parameters of thermal processing. Contemporary technological solutions aim at improving the heat exchange rate, shortening processing time and improving nutritive and sensoric value of prepared dishes.

Recently convection ovens have gained high popularity where forced convection has been applied using hot air or steam as heating agent. Application of one of the heat carriers or their combination facilitates carrying out different variants of cooking, roasting and dish restitution. Versatile character of a convection oven causes that it is widely used in food processing and in catering for preparing huge amounts of dishes in much shorter time and limiting mass loss of the product. On the market of catering equipment there are also smaller versions of convection ovens for households.

The purpose of this paper was to determine the effect of thermal processing in a convection oven on the quality of prepared dishes by means of testing quantitative and qualitative changes in selected indices of nutritive and sensoric value as compared to traditional methods. The investigations included raw materials and dishes (of animal and plant origin) most commonly used in Poland.

MATERIALS AND METHODS

The plant raw materials included two potato varieties: Bryza and Mile, and traditionally prepared sauerkraut of unknown variety. The animal origin material was pork – m. longissimus dorsi. The selection of this muscle was justified by the need of using material relatively homogenous with respect to tissue composition. After removal of external membrane (epimysium) the muscle was divided along the longer axis into three parts. The middle part was used for determining basic composition and indices of nutritive value of raw meat. The lateral parts were used for preparing dishes, i.e. boiled and roasted pork, boiled and fried minced meat balls. In preparation of the meat balls 2% addition of salt iodized with potassium iodide (30 mg/1kg $\pm$10 mg), made in Poland (Kopalnia Soli "Klodawa"), was used.

Both plant and animal raw materials and prepared dishes were subjected to thermal processing in a Rational Combi Dampfer convection oven (type CCC61-Rational Großkühentechnik GmbH, Landsberg, Germany) and, for comparison, to traditional methods (Table 1).

Table 1. Conditions of thermal processing of raw materials and dishes in convection oven and in conventional methods.

RAW MATERIALS-DISHES	CONVECTION OVEN			TRADITIONAL METHOD		
	Heating medium	Temperature [^{o}C]	Time [min.]	Heating medium	Temperature [^{o}C]	Time [min.]
Sauerkraut	Steam	100	35	Water	≈ 100 (boiling)	35
Potatoes	Steam	100	20-30	Water	≈ 100 (boiling)	25-40
Cooked meat	Steam	100	90	Water	≈ 100 (boiling)	90
Roasted meat	Steam/Air	180/180	40/30	Air	180	60
Cooked meat ball	Steam	100	7	Water	≈ 100 (boiling)	10
Fried meat ball	Air	230	8	Air	220	10

Selection of the optimal parameters of thermal treatment in the convection oven and by the traditional methods was preceded by initial trials, and the final decision about the heating conditions resulted from obtaining maximal sensoric acceptance. Thermal processing of all dishes made with traditional methods using electric oven started from the moment of achieving required temperature. The pots made from stainless steel were used.

For frying and roasting meat hardened plant fat "Planta" was used. Meat and the dishes (boiled and fired meat balls) in both thermal processing variants had similar mass and geometrical shape to maintain identical conditions determining kinetics of the thermal treatment.

The quantitative changes in vitamin C and in neutral detergent fiber (NDF) were used as indices of nutritive value of the dishes of potatoes and sauerkraut. The vitamin C content was determined with titration method according to Tillmans [22]. The dietary fiber (NDF) content was determined with a modified Van Soest's method [20,25]. The results of measuring of both indices are given in absolute values in relation to raw material or dish mass.

The quantitative and qualitative changes in thiamine, collagen and retention of iodine introduced into the product with the salt were taken into consideration as the index of nutritive value of meat dishes. The selection of the measurement of quantitative and qualitative changes in thiamine resulted from the fact that pork, after cereal raw materials and products, is a significant source of this vitamin in the diet. Recognition of the factors determining thermohydrolysis of collagen is a measure of consumption – sensoric usefulness of meat [2,16,18].

The quantitative and qualitative changes in thiamine were determined with a thiochromium method [23]. The results were given as non-fat dry mass.

Total collagen content basing on colorimetric measurement of hydroxyproline amount was made according to Bergman and Loxley [4] and for recalculating hydroxyproline into collagen coefficient 7.14 was used [9]. Soluble collagen content was determined with Hill's method [12] modified by Janitz [14]. Collagen content is given in g per 100g of total protein.

In determining inorganic iodine the method worked out by Kühne and Wagner [17] was used and the results were given in relation to dry mass of the raw material and the product.

Sensoric evaluation of prepared dishes was carried out by panelists (trained team–8 persons, with majority of women, at the age of 25-35 years) according to the triangle method [3]. Sensoric evaluation was carried out in laboratory of sensoric analysis, realizing basic requirements for sensoric laboratory. During two sessions of sensoric evaluation three triangles of coded samples for each persons were served. Samples of dishes were coded by computer program-Analsens. Dishes were served on white plates, keeping similar serving conditions. Panelists were asked for: indication of different sample and indication of preference of the sample. Answers to both questions were interpreted separately.

Statistical evaluation of the results was carried out with the one-way analysis of variance [11].

RESULTS AND DISCUSSION

Quantitative changes in vitamin C and fibre in potatoes and sauerkraut

The significant differences between the amount of ascorbic acid and food fiber in raw material and final dishes related to used thermal processing were found (Table 2).

Table 2. Changes in vitaminC and neutral detergent fiber (NDF) content in potatoes and sauerkraut depending on thermal processing method.

Way of cooking	Potatoes				Sauerkraut			
	Vitamin C content mg/100g product		NDF content g/100g product		Vitamin C content mg/100g product		NDF content g/100g product	
	X	sd	X	sd	X	sd	X	sd
Raw material	13.7^{a*}	0.1	0.61^{a}	0.01	23.3^{a}	0.2	1.27^{a}	0.01
Convection oven	7.8^{b}	0.2	0.84^{b}	0.03	16.1^{b}	0.3	1.54^{b}	0.01
Traditional method	6.8^{c}	0.2	0.95^{c}	0.02	10.3^{c}	0.4	1.45^{c}	0.01

Legend:

*-means in the same columns with different letters are significantly different($p<0.05$)
X-mean value
sd-standard deviation

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At the same time it was found, considering statistical objectivization ($p<0.05$), that thermal processing of potatoes and sauerkraut in the convection oven causes lower loss of vitamin C than that using traditional methods. Vitamin C losses in boiled potatoes with respect to its content in raw potatoes were at the level of 43.1% using the convection method, and 50.4% in the case of the traditional one. More significant differences in the vitamin C losses related to the thermal processing method occurred during cooking of sauerkraut amounting to 31.0% and 55.8%, respectively for convection and traditional methods.

Vitamin C, whose main source are vegetables, is one of the most unstable nutrients sensitive to oxygen, high temperature and ultraviolet radiation action. Since the same thermal parameters were used for both methods (100 ^{o}C) the limitation of ascorbic acid elution by water is only one reason for decreasing the degradation of ascorbic acid during the convection boiling.

In water environment – traditional boiling – elution of ascorbic acid is much greater than in steam. Kinetics of losses in this vitamin in potatoes was also determined by the time of high temperature action. The differences here reached even 10 minutes.

Generally it should be assumed that cooking potatoes and sauerkraut in convection oven causes smaller losses in vitamin C. In the case of potatoes the losses, as compared to traditional cooking in water, are lower by almost 10% and those in sauerkraut by over 20%.

Measurement of fiber content – neutral detergent residue (NDF), also indicated significant effect of applied thermal processing method at simultaneous effect of used raw material (Table 2).

In both vegetables each method of thermal processing resulted in an increase in NDF content as compared to initial raw material. It is worthwhile noticing that the increase in NDF in potatoes concerned particularly cooking in water, while in sauerkraut in steam.

Probably the main reason of this increase is formation of, so called, resistant starch (RS) due to thermal processing. Although this starch is not a component of fiber, it is poorly digested in intestine especially following thermal processing. It was found that about 20% of starch moves into colon in indigested form [5]. Following thermal processing tacky starch is subject to retrogradation and does not undergo enzymatic hydrolysis catalyzed by amylases. According to Englyst and Macfarlane [8] the amount of resistant starch formed during thermal processes depends on such factors as water content, pH, heating and cooling temperature. It is also possible, the thermal treatment, irrespective of used medium, caused formation of Maillard's reaction products whose presence determined results of NDF measurements in both vegetables. Increase in NDF content in raw materials subjected to thermal processing is probably due to thermal processes resulting in formation of products of Maillard's reaction and other indigestible residues apparently increasing amount of lignin [1, 6, 19].

Quantitative and qualitative changes in thiamine and collagen in meat and meat dishes

Each of the investigated variants of thermal processing of meat and its products significantly affected quantitative changes in total thiamine. They consisted in losses of this vitamin in the range of 50 to 60% (Table 3 and Table 4). The use of the convection oven effected the lower (about 5%) losses of total amount of thiamine (sum of free and bound thiamine) than traditional methods. Quantitative analysis of both forms, i.e. free and bound thiamine, in pork

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indicated that the balance of total thiamine loss was mainly affected by the losses in its bound form. The phenomenon of greater thermolability of bound thiamine as compared to free form was documented in earlier studies [7, 10]. In the case of the discussed study results it is important to notice that in fried meat balls losses of bound thiamine were the greatest with respect to free one. The disproportion here reached 30%. Boiling meat in one piece caused difference only by about 5%. These differences are additionally proven by a particular thermal sensitivity of bound thiamine with respect to free form. Frying of comminuted meat (meat balls) independently of the used method enhances thermal penetration of hot fat. It should be supposed that, besides thermal conditions, a significant causative factor here was direct action of products of fat oxidation on thiamine [7, 13, 24].

Table 3. Quantitative and qualitative changes of thiamine in cooked and roasted meat depending on thermal processing method.

Thermal processing		Thiamine content mg/100g non-fat dry mass							
		total			free form			bound form	
		X	sd	%	X	sd	%	X	%
Cooking	Raw meat	3.94^{a*}	0.06	0	2.76^{a}	0.05	0	1.18	0
	Convection oven	1.89^{b}	0.04	52.03	1.36^{b}	0.03	50.72	0.53	55.08
	Traditional method	1.69^{c}	0.03	57.11	1.24^{c}	0.02	57.11	0.45	61.86
Roasting	Raw meat	3.14^{a}	0.05	0	2.01^{a}	0.03	0	1.13	0
	Convection oven	1.60^{b}	0.03	49.05	1.14^{b}	0.03	43.28	0.46	59.29
	Traditional method	1.45^{c}	0.03	53.82	1.04^{c}	0.03	48.26	0.41	63.72

Legend:

%-thiamine losses in comparison with thiamine content in raw meat
*-means in the same columns with different letters are significantly different ($p<0.05$)
X-mean value
sd-standard deviation

Table 4. Quantitative and qualitative changes of thiamine in fried and cooked minced meat balls depending on thermal processing method.

Thermal processing		Thiamine content mg/100g non-fat dry mass							
		total			free form			bound form	
		X	sd	%	X	sd	%	X	%
Fried meat ball	Raw meat	3.11^{a*}	0.02	0	2.07^{a}	0.02	0	1.05	0
	Convection oven	1.29^{b}	0.03	58.52	1.04^{b}	0.03	49.76	0.25	76.19
	Traditional method	1.12^{c}	0.03	63.99	0.93^{c}	0.02	55.07	0.19	81.90
Cooked meat ball	Raw meat	3.02^{a}	0.04	0	2.03^{a}	0.04	0	0.99	0
	Convection oven	1.34^{b}	0.03	55.63	1.09^{b}	0.05	46.30	0.25	74.75
	Traditional method	1.12^{c}	0.04	62.91	0.99^{c}	0.03	51.23	0.12	87.88

Legend:

%-thiamine losses in comparison with thiamine content in raw meat
*-means in the same columns with different letters are significantly different ($p<0.05$)
X-mean value
sd-standard deviation

In the case of meat boiled in one piece, besides thermal factor (relations of quantitative changes in free and bound thiamine), a significant determinant of the losses of this vitamin was its migration with meat juice into external environment. Traditional thermal processing-water and comminuting of meat – boiled meat balls, caused the highest losses in total thiamine (over 60%).

All in all it should be stated that the use of convection oven for cooking pork dishes secures lowering of losses in thiamine on average by 5% as compared to traditional methods. This small percentage of "vitamin profit" has, however, its importance considering that in Polish conditions of quantitative and qualitative consumption, pork is, after cereals, a significant source of thiamine in diet.

Measurement of quantitative and qualitative changes in collagen after thermal processing was limited exclusively to the variant of meat boiling. Determination of total and soluble collagen content enabled balancing quantitative changes in the fraction of insoluble collagen.

Statistical analysis of the results indicated significance of the observed differences ($p<0.05$) resulting from the method of meat cooking (Table 5). Steaming in convection oven resulted in slightly lower collagen losses. Total collagen content in meat following thermal processing in a convection oven was 50% of that in raw material while in the case of traditional cooking it was almost 47%. The effectiveness of thermal fragmentation (thermohydrolysis) of collagen in a convection oven was also a little lower than in traditional cooking in water. In the meat subjected to thermal processing in a convection oven there was less soluble collagen and more insoluble one. These quantitative and qualitative relations of collagen between thermal processing in a convection oven and by traditional methods would be different if boiling was carried in a traditional way where water and meat reach boiling point simultaneously. Elution and related migration of collagen into water would be greater.

Table 5. Quantitative and qualitative changes of collagen in boiled pork.

Way of cooking	Collagen content in g/ 100g total protein							
	total			soluble			insoluble	
	X	sd	%[1]	X	sd	%[1]	X	%[1]
Raw meat	3.21[a*]	0.26	100	0.15[a]	0.03	100	3.06	100
Convection oven	1.62[b]	0.03	50.47	0.30[b]	0.01	200	1.32	43.14
Traditional method	1.50[c]	0.05	46.73	0.34[c]	0.01	226.8	1.16	37.91

Legend:

%[1]- total, soluble or insoluble collagen content were compared to similar collagen content in raw meat

*-means in the same columns with different letters are significantly different ($p<0.05$)

X-mean value

sd-standard deviation

It can be assumed that cooking in a convection oven results in lower quantitative losses in collagen and the degree of its fragmentation is "competitive" for cooking meat placed directly in boiling water. It should be also said that observed lowering of the degree of collagen thermohydrolysis does not affect negatively quality of meat prepared in a convection oven. Sensoric evaluation with a triangle method indicated significant differences in tenderness of meat prepared using both methods, and the tenderness of pork cooked with convection method was preferred.

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The effect of conditions of thermal processing on retention of iodine in boiled and fried meat balls

An addition of 2% of iodized salt to minced pork for boiled and fried meat balls was reflected in a variable quantity of inorganic iodine in these dishes (Table 6). Irrespective of the kind of thermal processing – heating medium and kind of dish, application of convection oven gave much lower losses in inorganic iodine with respect to its amount in the initial raw material. Using hot air as heating medium as compared to traditional frying of fried meat balls lowered iodine losses almost six times. Cooking boiled meat balls in steam lowered iodine losses by about 20% compared to traditional boiling in water. These iodine losses are mostly due to its migration into external environment and to trickling of meat juices. Traditional cooking of e.g. boiled meat balls, particularly favours this phenomenon which was reflected in almost 65% loss of this element. Application of hot air causing quick denaturation of muscle proteins on the meat ball surface limited iodine losses only by 5.5%. The results of numerous studies show that iodine introduced to meat systems can be bound by organic compounds what limits the use of classical methods for determination of iodine content in meat products [17, 21].

Table 6. Iodine retention in cooked and fried minced meat balls depending on conditions of thermal processing.

Thermal processing	Iodine content in mg/100g dry matter					
	Cooked meat ball			Fried meat ball		
	X	sd	%	X	sd	%
Raw meat	81.1[a*]	0.4	0	71.4[a]	0.3	0
Convection oven	46.3[b]	0.5	42.9	67.5[b]	0.5	5.5
Traditional method	28.5[c]	0.5	64.9	48.8[c]	0.7	31.7

Legend:

%-iodine losses in comparison with iodine content in raw meat
*-means in the same columns with different letters are significantly different ($p<0.05$)
X-mean value
sd-standard deviation

Using convection oven as a source of steam and hot air in thermal processing of meat dishes enables quite successful retention of iodine introduced with salt into products. Application of hot air as heating medium considerably lowers losses of this element whose deficiency in our diet is now quite worrying [15].

Sensoric evaluation of the dishes

Sensoric evaluation of the dishes from plant raw materials, boiled potatoes and sauerkraut, consisted in evaluation of the smell, texture and taste. In the case of Mile variety potatoes and sauerkraut cooking in convection oven with steam the product was decisively better than cooked traditionally. Every analysed index of sensoric evaluation was valued higher as compared to traditional cooking. Whereas in the case of Bryza variety potato only taste turned out to be more attractive following cooking in a convection oven. Smell and texture of these potatoes did not reveal significant differences with respect to both methods of preparation.

For both plant raw materials using steam as heating medium proved to be most favourable for sensoric reception of the dishes. It is worthwhile noticing that advantages of steam in thermal processing are selective and even a variety of vegetable can decide about sensoric parameters of a dish.

Sensoric evaluation of the meat dishes took into account their smell, taste, tenderness, juiciness and colour on the surface and cross-section. Sensoric preferences of dishes depend on the method and parameters of thermal processing. Roasting of meat in a traditional way dominated thermal processing in the oven. Each index of the evaluation achieved better marks for the meat roasted traditionally. Using convection oven in the case of boiling meat and meat balls was better for quality of these products. Results of traditional boiling of these dishes in water gave lower values of all indices. This undisputably indicates that water as a heating medium causes lowering of sensoric value due to migration of meat juice and advancement of thermal transformations in meat proteins.

Thermal processing of fried meat balls also indicated selective effect of the used methods with respect to tested evaluation indices. In the case of colour, particularly on the surface of a dish, traditional frying method was preferred. The remaining results of sensoric evaluation of fried meat balls preferred the use of convection oven.

Summing up, the use of convection oven guarantees good quality of the dishes (particularly the cooked one) for the potential consumer.

CONCLUSIONS

1. Cooking potatoes and sauerkraut in a convection oven lowers losses in vitamin C as compared to traditional cooking in water. The losses are lower by 10% in potatoes and by 20% in sauerkraut.
2. Differences in the plant raw materials, i.e. sauerkraut and potatoes, and the methods of their cooking significantly determined food fiber (NDF) content in both vegetables. Taking into account nutritive aspects related to the need of enriching our diet with fibre, cooking potatoes in water and sauerkraut in a convection oven should be preferred.
3. Cooking and roasting meat in a convection oven lowers total thiamine loss on average by 5% as compared to traditional boiling and roasting.
4. Thermal destruction of collagen – thermohydrolysis, in the process of meat cooking is more advanced following traditional thermal processing than after cooking in a convection oven. However, these differences were not reflected in sensoric evaluation of tenderness of the boiled meat.
5. Thermal processing of meat dishes from comminuted meat in convection oven yields lower losses in inorganic iodine introduced with salt. As compared to traditional thermal treatments losses of this element in boiled meat balls were lower by 22% and in fried ones by 26%.
6. Sensoric quality of the dishes after thermal processing – cooking in a convection oven is higher valued than after cooking in water.

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Submited:

Katarzyna Waszkowiak, Krystyna Szymandera – Buszka, Witold Janitz, Danuta Gorecka
Department of Human Nutrition Technology
University of Agriculture,
Wojska Polskiego 31, 60-624 Poznan, Poland.
