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Glucosinolates and Myrosinase Activity in Red Cabbage (*Brassica oleracea* L. Var. *Capitata* f. *rubra* DC.) after Various Microwave Treatments

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Total and individual levels of glucosinolates (GSs) were measured in red cabbage after various microwave treatments varying in time and intensity of the treatments. Furthermore, the myrosinase enzyme activity of the microwave-heated vegetables was determined. The retention of GSs in the cabbage and the residual activity of the hydrolytic enzyme as a result of microwave preparation were compared with untreated cabbage. In general, high total GS levels were observed for all of the applied microwave treatments. Strikingly, many of the time/energy input combinations resulted in levels exceeding the total GS content of the untreated cabbage material. Moreover, the increase in levels seems to be associated with the energy input applied. A possible explanation for this behavior is an increased extractability of GS from heat-treated cabbage as compared to raw cabbage. Substantial myrosinase activity was retained in cabbage treated at low (24 min, 180 W) and intermediate microwave powers (8 min, 540 W) while microwave cooking for 4.8 min at 900 W (259.2 kJ energy input) resulted in a complete loss of hydrolytic activity. In this respect, differences in observed temperature profiles of the various microwave treatments play an important role. Higher retention of GSs and controllable amounts of active myrosinase can offer increasing health-promoting properties of microwave-prepared *Brassica* vegetables.

KEYWORDS: Glucosinolates; myrosinase; microwave cooking; health protection; *Brassica oleracea*

INTRODUCTION

Glucosinolates (GSs) are a group of secondary plant metabolites that occur in crops belonging to the family of Brassicaceae. The widely cultivated, economically important vegetables such as broccoli, cauliflower, cabbage, and Brussels sprouts are the major sources of GSs in the human diet. In the past few years, *Brassica* vegetables have received more attention due to the health-promoting properties ascribed to the GSs. The particular interest in GSs for the food research is based on their anticarcinogenic properties and also because of their contribution to the characteristic flavor and odor of many *Brassica* vegetables. Specific hydrolysis products of GSs are responsible for these important properties. When the plant tissue is damaged by food preparation or mastication of the vegetables, the GSs are brought into contact with and hydrolyzed by the endogenous plant enzyme myrosinase (thioglucoside glucohydrolase EC 3.2.3.1), releasing a broad range of breakdown products including isothiocyanates and indoles.

The level of GSs ingested by humans depends on a variety of factors along the complete production chain of *Brassica* vegetables (*1*). Most likely, processing and food preparation of the vegetables affect mostly the GS content and consequently determine the final intake levels of health protective compounds. Processes such as chopping, cooking, or freezing influence the extent of hydrolysis of GSs and the composition of the final hydrolysis products. As most vegetables are processed in some way before consumption, the effects of processing should be taken into account in order to make accurate estimates of dietary intake of these protective compounds (*1*). Hence, control of GS levels and myrosinase activity in *Brassica* vegetables is highly desirable.

Various studies on different phytochemicals have shown that conventional cooking can lower their contents in foods. Examples such as folate in spinach (*2*) and in broccoli (*3, 4*) show large losses caused by leaching of the protective compounds in the cooking water. Also, considerable reductions of GSs levels are demonstrated in different studies (*5*−*8*). Rosa and Heaney (*9*) analyzed the effects of cooking of different cabbage types and measured individual and total GS levels in the cooked leaves and the cooking water. It appeared that the GS content of the cabbages was reduced by more than 50%, mostly ascribed to leaching of the GSs into the cooking water. However, the effects of cooking of *Brassica* vegetables on the hydrolytic activity of the enzyme myrosinase are hardly studied. Besides the GSs, the presence of an active plant myrosinase is a prerequisite for formation of protective breakdown products.

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That is to say, the highest release of protective breakdown product can take place during mastication of the vegetables.

Microwave cooking is an interesting alternative way of cooking with little or no water needed for preparation of the vegetables. Therefore, leakage of GSs is limited and higher retention of GSs and breakdown products in the *Brassica* vegetables can be expected. Vallejo et al. (*8*) investigated the effects of various cooking treatments of vegetables on the GS content. In their study, microwave cooking of broccoli for 5 min at 1000 W resulted in a substantial reduction of total GS content (74%) with hardly any GSs in the residual water. The use of microwave energy rather than conventional methods to cook food results in savings in energy and time, improved acceptability of some foods by consumers, and improved nutritive quality of many foods. Research has considered the convenience and consumer satisfaction of microwave-heated foods and inactivation of spoilage and pathogenic microorganisms by microwave energy. Special interest goes to the high retention of nutrients in microwave-prepared foods. It should be stated that the energy input into food could vary among the various types and models of domestic microwave ovens.

The aim of this study was to investigate the behavior of the GS/myrosinase system in red cabbage during a broad range of microwave treatments varying in time and power (energy input). The GS content and the hydrolytic activity of myrosinase were measured in red cabbage samples treated at high power and short heating times in comparison with treatments at low power and long heating times. The overall effects of microwave cooking on the protective capacity of cabbage are discussed with respect to the intake of GSs and health protective breakdown products as compared to conventional cooking methods.

MATERIALS AND METHODS

Sample Preparation. Red cabbage (*Brassica oleracea* L. var. *Capitata* f. *rubra* DC) material was purchased from local supermarkets (Wageningen, The Netherlands). The outer leaves of the heads were removed, and complete cabbage heads were used for the experiments. The cabbage was chopped into pieces of approximately 1 cm and mixed thoroughly. For GS analysis of the fresh cabbage, the chopped material was directly frozen with liquid nitrogen. The frozen material was ground in a Waring Blender (model 34BL99, Dynamics Corp. of America, New Hartford, CT) and stored at −20 °C until further analysis.

Preparation of Cabbage Juice for the Analysis of Myrosinase Activity. The red cabbage material was chopped, and the juice was prepared with a commercial juice centrifuge (Braun, type 4290). After the microwave treatment, 200 g of cabbage was cooled on ice until 23 °C and juiced. The obtained juice was sieved to remove the larger parts. Subsequently, the juice was incubated for 1 h at 40 °C in an oven to hydrolyze the endogenous GSs present in the cabbage. The obtained batch of GS-free juice was considered as a crude myrosinase extract in which different cabbage components are present that could affect the myrosinase activity (e.g., ascorbic acid). Part of the juice was incubated for 15 min at 100 °C in order to inactivate the enzyme myrosinase. This juice was used for dilution purposes in the activity assays.

Microwave Cooking. Approximately 2 kg of red cabbage was chopped (1 cm^2) and divided into portions of 300 g each. Each portion was placed in a 500 mL beaker and cooked in a microwave oven (Daewoo, model KOC-87-T, Korea) at 2450 MHz according to the scheme in **Table 1** (without water). After the microwave treatment, a subsample of 100 g was taken for analysis of desulfated GSs. The vegetables were frozen with liquid nitrogen, ground in a Waring Blender, and stored at −20 °C until analysis. The remaining 200 g of cabbage was used for the preparation of juice for the analysis of the hydrolytic myrosinase activity. The total energy input of a microwave treatment (Joules) is the result of applied power multiplied by the time of exposure (seconds).

Table 1. Heating Scheme of Red Cabbage Samples According to Different Powers and Heating Times

treatment	energy input (kJ)	180 W	540 W	900 W
A	32.4	3 min	1 min	36 s
B	64.8	6 min	2 min	1 min 12 s
C	129.6	12 min	4 min	2 min 24 s
D	194.4	18 min	6 min	3 min 36 s
E	259.2	24 min	8 min	4 min 48 s

Separate experiments were carried out for the temperature registration of cabbage samples during microwave cooking. The temperature of cabbage samples was measured in a Whirlpool microwave (type m506, 750 W output) using a glass fiber probe (Takaoka, Type FTP3-3003 s/n 31888). The probe was inserted, via an opening in the microwave, in the middle of chopped portions of red cabbage. The obtained data (time/temperature profiles) were used for the development of a predictive temperature model.

High-Performance Liquid Chromatography (HPLC) Analysis of GSs. The GSs were analyzed in the fresh cabbage or cabbage juice using HPLC following on-column desulfation as described by Verkerk et al. (*10*).

Determination of Myrosinase Activity. The activity of the enzyme myrosinase present in the juice is measured by hydrolysis of a known amount of sinigrin added to the juice. To 5.0 g of cabbage juice, 1 mL of 6 mM sinigrin was added and incubated at 40 °C for 0, 5, 10, and 20 min. The reaction was stopped by adding 12 mL of 100% hot methanol (for 10 min at 75 °C). The juices were centrifuged (5000*g*, 10 min, room temperature), and the remaining sinigrin was isolated from the collected supernatant and analyzed by HPLC.

Modeling of the Temperature in Cabbage during Microwave Heating. Time−temperature profiles within a food product are influenced by both internal heat generation due to absorption of electrical energy from the microwave field and heat transfer by conduction, convection, and evaporation (*11*). Microwave heating is complicated and not easily modeled because the rate of energy absorption and energy distribution is controlled by the physical, thermal, and electrical properties of the product and the variation with temperature during radiation. In this study, modeling of the cabbage temperature was simplified with the assumption that the $T_{c,max} = 100$ °C. The specific food properties (e.g., density, specific heat) were not characterized individually but were lumped in the energy conversion and heat transfer coefficients. During the process of microwave heating, the cabbage will also transfer heat to the surroundings that subsequently warms.

The model was based on the energy input, cabbage weight, and heat transfer to the surroundings (eqs 1 and 2).

$$\frac{dT_c}{dt} = k_1 \frac{P}{m} - k_2(T_c - T_{sur}),\ T_c \le T_{c,max} \quad (1)$$

$$\frac{dT_{sur}}{dt} = k_3(T_c - T_{sur}),\ T_{sur} \le T_{sur,max} \quad (2)$$

in which T_c is the temperature of the cabbage (°C) and T_{sur} is the temperature of the surroundings increasing in time t (s) and P (Watt) refers to the applied microwave power on the mass m (g) of the cabbage. k_1 is an energy conversion coefficient (°C g J^{-1}) and k_2 and k_3 are heat transfer coefficients (s^{-1}).

The parameters in eqs 1 and 2 were estimated from experimental data obtained from microwave treatments of 100, 200, and 300 g of red cabbage upon heating at 150, 450, and 750 W for varying times.

Data Analysis. Statistical analysis of the data was performed on the original data by one-way analysis of variance using the statistical package from Microsoft Excel software. Fitting of the model equations on the experimental data has been done by minimizing the sum of squares of the relative errors between model prediction and measured

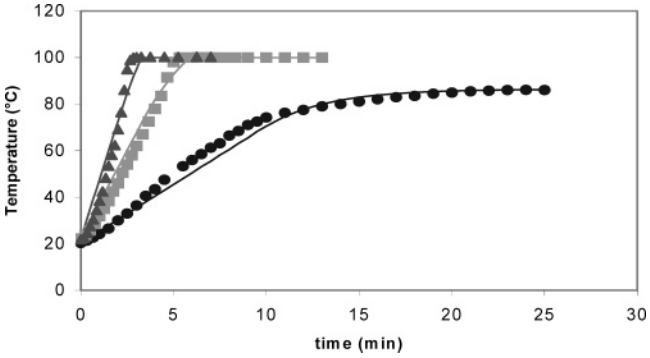

Figure 1. Temperature profiles of 300 g of red cabbage microwave heated at 150 (●), 450 (■), and 750 (▲) W; solid lines are the model fits.

Table 2. Estimation of Heat Transfer Parameters

	parameters[a]
k_1	10.7 °C g J^{-1}
k_2	0.26 s^{-1}
k_3	4.0 s^{-1}

[a] Parameters k_2 and k_3 are fitted for a cabbage weight of 300 g. These parameters can deviate when using different weights.

Table 3. Average Levels (μmol 100 g^{-1} FW) of the Main GSs Identified by HPLC in Untreated (Fresh) Red Cabbage

no.	structure of R group	trivial name	[C][a]	SD
1	2-propenyl	sinigrin	33.0	2.2
2	MSB	glucoraphanin	20.8	2.7
3	4-hydroxy-3-indolylmethyl	4-hydroxyglucobrassicin	5.4	0.8
4	3-indolylmethyl	glucobrassicin	8.6	1.3
5	4-methoxy-3-indolylmethyl	4-methoxyglucobrassicin	8.8	0.9
		total	76.6	7.9

[a] Mean concentrations of the five different batches (A–E) of red cabbage.

data using nonlinear regression with the "solver" routine of Microsoft Excel 97.

RESULTS

Temperature Profiles. The measured temperatures of the cabbage microwave heated at different power inputs were fitted to model eqs 1 and 2 (**Figure 1**). Microwave cooking at 450 and 750 W resulted in a temperature of the cabbage of 100 °C reached within 5 and 3 min, respectively, and remained constant after that time. On the other hand, the cabbage microwave treated at 150 W rose in temperature considerably slower and did not reach higher than 86 °C after 25 min of exposure (**Figure 1**). With the use of the developed model, temperature profiles of different powers could be predicted. The obtained model parameters are presented in **Table 2**.

Total and Individual GSs. The main GSs identified in the red cabbage are listed in **Table 3**. The GSs 2-propenyl and 4-methylsulfinylbutyl (MSB) together represent 70% of the total amount of GSs. These two types of GSs are responsible for the important characteristics of flavor (sinigrin) and health protection (glucoraphanin) of red cabbage, respectively.

Different batches of red cabbage were used for the applied energy inputs A, B, C, D, and E. This caused some variation in the individual and total GS levels between batches (**Table 3**). Substantial variations in GS content between and within *Brassica* groups have been reported earlier (*12*, *13*). Genetic factors and environmental factors are supposed to both contribute significantly to the variation in levels of GSs.

Table 4. Total and Individual GS Levels in Red Cabbage after Different Microwave Treatments[a] [Concentration in μmol 100 g^{-1} FW; Concentration Relative to Untreated Cabbage (Expressed as %) Is Indicated in Parentheses][a]

treatment	control	180 W	540 W	900 W
		(A) total GSs		
A	72.2	74.4 (103)	73.1 (101)	80.5 (111)
B	81.0	77.9 (96)	71.0 (88)	85.0 (105)
C	83.6	85.1 (102)	118.9(142)**	112.9(135)**
D	74.0	128.8(174)**	103.1 (139)*	99.5 (134)*
E	71.9	115.2(160)**	103.0 (143)*	128.0(178)**
		(B) 2-propenyl		
A	31.2	40.6 (130)*	33.9 (109)	41.0 (132)
B	35.5	38.8 (110)	26.5 (75)	37.4 (105)*
C	41.0	47.3 (115)	58.6 (143)**	56.8 (139)**
D	29.0	64.6 (223)*	40.4 (139)	42.2 (146)*
E	28.2	56.9 (202)*	47.9 (170)**	66.7(237)**
		(C) MSB		
A	20.0	14.2 (71)**	17.9 (89)	19.4 (97)
B	21.5	15.9 (74)**	17.7 (82)*	18.2 (85)
C	23.3	17.1 (73)**	28.1 (121)*	22.0 (95)
D	21.1	23.8 (113)*	27.0 (128)	20.6 (98)
E	18.1	17.6 (98)*	20.4 (113)	21.1 (117)
		(D) 4-hydroxy-3-indolylmethyl		
A	4.6	3.1 (69)*	3.5 (76)	3.3 (71)
B	6.4	4.7 (74)	5.5 (87)*	5.0 (78)
C	5.5	3.6 (66)**	6.8 (124)**	5.9 (108)*
D	5.6	7.0 (125)*	6.7 (119)**	7.4 (132)**
E	5.1	8.1 (159)**	6.7 (132)**	9.0 (178)**
		(E) 3-indolylmethyl		
A	9.6	11.2 (116)	12.4 (128)*	10.9 (113)
B	8.3	8.2 (99)	14.7 (177)	14.3 (172)
C	5.5	9.8 (180)	16.3 (297)	18.2(333)**
D	9.2	18.1 (196)*	17.7 (193)	20.7(225)**
E	10.6	17.6 (166)*	18.6 (176)	18.4(174)**
		(F) 4-methoxy-3-indolylmethyl		
A	6.8	5.2 (77)**	5.4 (79)**	5.6 (86)
B	9.5	10.3 (109)*	6.6 (70)*	10.2 (108)
C	8.4	7.3 (87)	9.2 (110)*	10.0 (119)**
D	9.1	15.4 (169)**	11.3(124)**	8.6 (95)
E	10.1	15.0 (149)*	9.5 (95)	12.8 (127)**

[a] Significant difference: *$P < 0.05$; **$P < 0.01$. [b] Treatments were performed in duplicate.

Effect of Microwave Treatments on GS Content. The total GS contents in red cabbage after the different microwave treatments are presented in **Table 4A**. The relative change in GS content was calculated for each cabbage batch. In general, high total GS levels were observed for all of the applied microwave treatments. It is striking that many of the time/energy input combinations resulted in levels exceeding the total GS content of the untreated cabbage material. Moreover, the increase in levels seems to be associated with the energy input applied (**Figure 2**). The total GS content of red cabbage microwave treated for 3 min at 180 W (32.4 kJ) increased from 74.4 ± 4.3 μmol 100 g^{-1} fresh weight to 128.0 ± 5.2 μmol 100 g^{-1} fresh weight when cooked for 4 min 48 s at 900 W (259.2 kJ). This latter more intense microwave treatment resulted in a 78% increase of the total GS content as compared to the control ($P < 0.01$).

Despite the large increase of the total GS content, there are remarkable differences in the behavior of individual GSs for the different microwave treatments. As the GSs 2-propenyl and MSB represent most of the GSs in red cabbage, they determine mainly the course of the total GS content. The GS 2-propenyl (sinigrin) presented in **Table 4B** showed a substantial increase especially at higher energy inputs (treatment E). The 2-propenyl concentration was 102, 70, and 137% higher for treatments E180

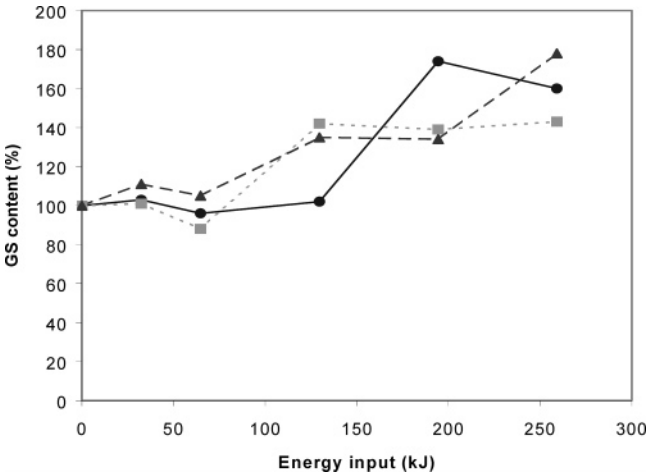

Figure 2. Effect of different microwave energy inputs on the total GS content in red cabbage: 180 (●), 540 (■), and 900 (▲) W.

($P < 0.05$), E540 ($P < 0.01$), and E900 ($P < 0.01$), respectively, as compared to the untreated samples of the same cabbage batch. However, MSB (glucoraphanin) GS levels decrease at lower energy inputs (treatments A and B) after which some treatments showed a small increase at higher energy inputs (**Table 4C**). However, as a whole, the different microwave treatments do not show a notable effect on MSB GSs.

GS levels of the three 3-indolylmethyl GSs generally also showed an increase with increasing energy inputs (**Table 4D−F** and **Figures 3−5**). Significant increases were noted in the 4-hydroxy-3-indolylmethyl GS content for treatments D (194.4 kJ) and E (259.2 kJ) as compared to the untreated cabbage samples (**Table 4D**). There is a similar trend for 4-methoxy-3-indolylmethyl GSs although the values of D900 and E540 deviate from this having lower levels (**Table 4F**).

In the case of 3-indolylmethyl GSs, no decrease was observed; instead, all treatment (except for B180) resulted in levels exceeding the untreated samples. However, large variation in the measurements caused not all of the levels to be significantly increased (**Table 4E**). One remarkable observation in this respect is the trend of the highest increase at the intermediate microwave treatments C540 (129.6 kJ) and C900 (129.6 kJ) and the subsequent decline at more intense treatments E540 (259.2 kJ) and E900 (259.2 kJ).

Effect of Microwave Treatments on Myrosinase Activity. Because the presence of the enzyme myrosinase is crucial in the production of health protective breakdown products of GSs, it is important to assess the remaining hydrolytic activity in the cabbage after the various microwave treatments.

The activity of the enzyme myrosinase was determined in juices prepared from fresh and microwave-treated red cabbage samples. Previous research (unpublished) showed that juicing of cabbage resulted in a high myrosinase activity in the juice and little remained in the cabbage pulp. Because we are interested in the myrosinase activity at cellular conditions, measuring the activity in the juice of cabbage is preferred over the activity of the isolated enzyme, which is usually done (*14−17*). The presence of known (e.g., ascorbic acid, $MgCl_2$, and iron) and yet unknown components in the cabbage juice that are important for myrosinase activity gives a valuable advantage to this approach. After preparation of the juice, the existing myrosinase was tested for its ability to hydrolyze pure sinigrin added to the juice sample. In **Figure 6**, the amounts of convertible sinigrin are presented after 20 min of exposure to the juiced samples. This figure shows that the activity of

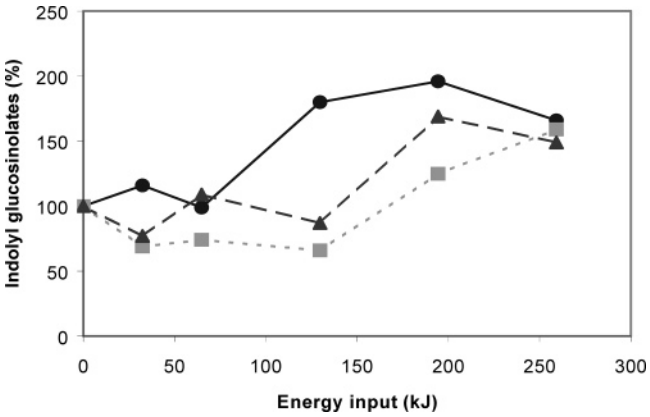

Figure 3. Effect of microwave energy inputs (180 W) on various indolyl GS contents: glucobrassicin (●), 4-hydroxyglucobrassicin (■), and 4-methoxyglucobrassicin (▲).

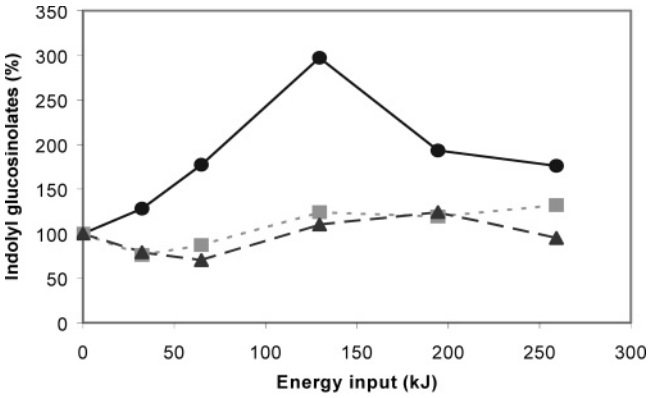

Figure 4. Effect of microwave energy inputs (540 W) on various indolyl GS contents: glucobrassicin (●), 4-hydroxyglucobrassicin (■), and 4-methoxyglucobrassicin (▲).

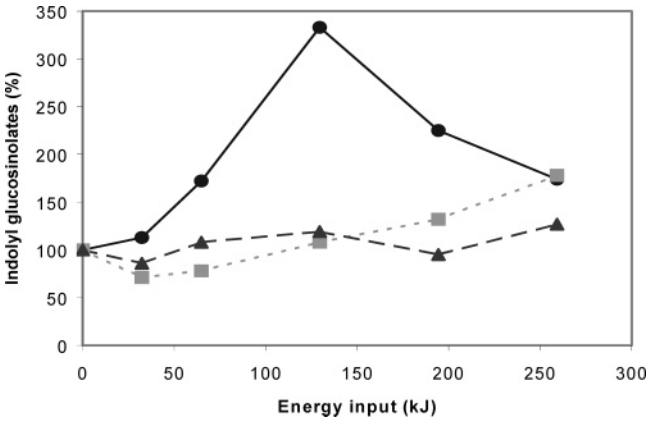

Figure 5. Effect of microwave energy inputs (900 W) on various indolyl GS contents: glucobrassicin (●), 4-hydroxyglucobrassicin (■), and 4-methoxyglucobrassicin (▲).

myrosinase diminished with increasing energy inputs. Cabbage microwave treated with the highest power (900 W) and the highest energy inputs (C900, D900, and E900) (almost) completely lost hydrolytic capacity.

The milder microwave-treated cabbage at 540 W resulted in a reasonable amount of myrosinase residual activity capable of converting the exogenous sinigrin even at higher energy inputs (treatments D and E). Cabbage treated at the lowest microwave powers (180 W) retained the highest myrosinase activities.

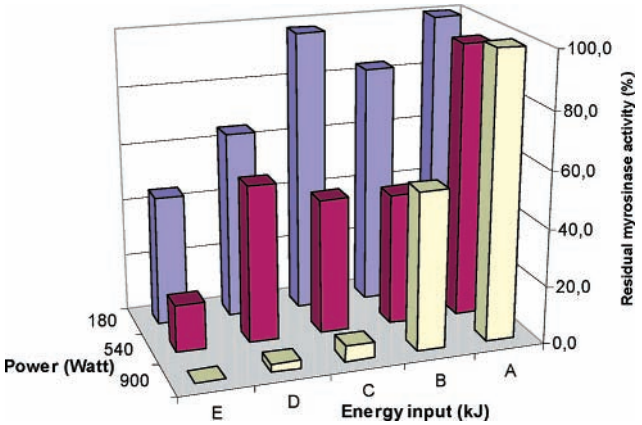

Figure 6. Residual myrosinase activity of red cabbage as a function of energy input to microwave. Energy inputs are as follows (in kJ): A, 32.4; B, 64.8; C, 129.6; D, 194.4; and E, 259.2 (expressed as % decrease of sinigrin in 20 min).

DISCUSSION

Different processes that can take place during microwave cooking determine the fate of GSs. In this respect, it is essential to realize that in intact cells of cabbage the membrane of the vacuole separates the enzyme from its substrate. First, hydrolysis will occur at the cutting surface of the chopped cabbage. Second, further membrane damage and cell rupture can be the result of increasing temperatures and microwave radiation. In the case of conventional cooking, cell lysis will occur giving rise to a sudden increase in an osmotic pressure difference over the vacuole membrane that will result in the collapse of this membrane and subsequent mixing of the GSs and the myrosinase in the cooking water. Enzymatic degradation can then take place. Third, myrosinase activity increases with moderate heat at temperatures up to about 60 °C, and inactivation will occur at higher temperatures.

GSs. In our study, microwave cooking of cabbage at low (180 W), intermediate (540 W), and high (900 W) energy inputs did not result in losses in GS levels in the cabbage as occurs during conventional cooking in water. Unexpectedly, many microwave treatments with varying energy inputs revealed total GS contents exceeding the levels present in untreated cabbage (**Figure 2**). This high retention probably reflects the absence of leaching of GSs into cooking water that takes place in conventional cooked vegetables. The process of cell disruption probably will take place when temperatures are reached unfavorably for the hydrolytic enzyme myrosinase. Especially at high microwave power (900 W), there is little opportunity for the hydrolysis of GSs taking place.

During the different microwave treatments of the cabbage samples, differences in behavior can be observed between the individual GSs. The microwave treatments did not reveal a large effect on MSB GSs, while 2-propenyl GS levels increased substantially.

According to Vallejo et al. (*8*), microwave cooking resulted in substantial losses of up to 74% of total GSs in broccoli, which is in disagreement with our results for red cabbage. It should be taken into account that different vegetables are used and broccoli is a much more fragile product than red cabbage. Moreover, a relatively large amount of water (150 g) was used for the broccoli treatment, possibly causing leaching of the GSs (*8*), while in our study no water was added to the microwave treatment of red cabbage.

Other studies of microwave treatments on levels of phytochemical compounds such as ascorbic acid (AA) and β-carotene (β-C) were studied in more detail. Howard et al. (*18*) reported no effects on the AA or β-C content after microwave cooking of broccoli for 8 min at 700 W.

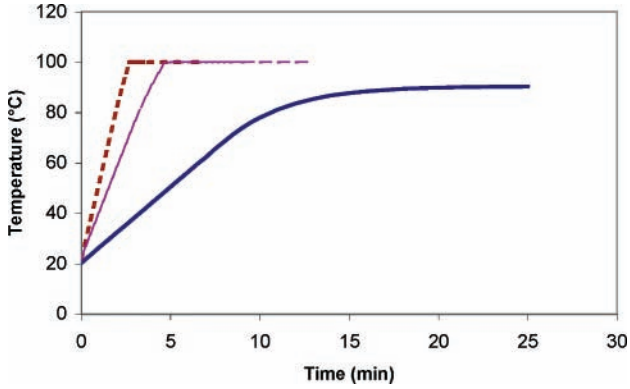

Figure 7. Temperature profile fits of 300 g of red cabbage microwave heated at 180 (solid line), 540 (dashed line), and 900 (dotted line) W.

In our study, microwave cooking decreased the moisture content of cabbage by evaporation causing elevated GS levels in the samples. However, a maximum weight loss of 20% after cooking was determined experimentally (not shown), and this could not explain the high increase of GSs. A possible explanation for this phenomenon is an increase in chemical extractability of the GSs after an intense heat treatment. Cooking has been reported to increase the extractability of carotenoids. Hart and Scott (*19*) showed in various green vegetables, peas, and beans an average increase of 24% lutein and 38% β-carotene. These substantial increases of health protective compounds after microwave cooking can have important consequences with respect to bioavailability of these compounds to humans.

Myrosinase. The activity of myrosinase is affected differently when vegetables are microwave cooked with varying time−power combinations but with the same total energy inputs. For example, substantial myrosinase activity was retained in cabbage after 24 min of microwave cooking at 180 W (259.2 kJ) while 4.8 min of microwave cooking at 900 W (259.2 kJ) resulted in complete loss of hydrolytic activity (**Figure 6**). Similar profiles were observed with treatments C (129.6 kJ) and D (194.4 kJ). An explanation for these differences can possibly be found in the temperature profiles fitted for the different applied microwave treatments (**Figure 7**).

Microwave cooking at 900 W resulted in a temperature of the cabbage of 100 °C reached after 2.8 min and continued cooking for another 2 min. Apparently, the myrosinase enzyme was denatured at these conditions. However, red cabbage microwave treated at 180 W rose in temperature considerably slower and did not reach higher than 90 °C after 25 min of exposure (**Figure 7**). Under these conditions, the more thermostable myrosinase (*14*) apparently can survive partly and maintain some hydrolytic activity. More difficult to explain were the myrosinase activities at the 540 W microwave-treated cabbage samples. Cabbage microwave treated at 540 W reached a temperature of 100 °C after 4.6 min and continued cooking for another 3.4 min. Striking in this treatment is the substantial remaining hydrolytic activities of 47, 55, and 17% after 4, 6, and 8 min, respectively, while cabbage treated at 900 W retained only 5.4 and 2.7% myrosinase activity after 3.6 and 4.8 min, respectively. Certain discrepancies in activity differences can be imputed to the microwave principle of going on and off to regulate the power output (cycling). Furthermore, moisture content during microwave heating is known to affect enzyme inactivation and/or denaturation of proteins (*20*).

The health benefits of vegetables are well-recognized, but vegetable intake in Europe is below recommendations. Food preparation methods such as conventional cooking reduce the intake of important potentially health protective and promoting compounds as GSs even more. From this study, it can be concluded that microwave cooking resulted in high retention of the GSs even exceeding, in some instances, the levels in untreated cabbage material. Therefore, microwave-cooked cabbage would result in a relatively higher intake of GSs as compared to conventional cooked cabbage in water. The residual activity of the hydrolytic enzyme myrosinase as obtained at certain milder microwave conditions can possibly also cause conversion of GSs into protective breakdown products during mastication of the vegetables. However, it should be investigated to what degree myrosinase is able to exert hydrolysis when it is partially inactivated.

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