Resistant starch in the Italian diet*

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Resistant starch (RS) has been defined as the sum of starch and starch-degradation products that reach the human large intestine (Champ, 1994), and it is now regarded as a sub-fraction of starch with a positive impact on colonic welfare and lipid metabolism. An early estimate of the RS intake in Europe gave an average value of approximately 4 g/d (Dyssler & Hoffem, 1994a). However, since no information is available for Italy, the aim of the present study was to estimate the intake of RS in the Italian diet by direct analysis of RS in a range of typical foods representing the main sources of starch intake in the country. The selection of representative foods and of food consumption data were based on published results of the National Food Consumption Study conducted during the 1980s by the National Institute of Nutrition on 10 000 households, using weighed-food records plus inventory methodologies (Saba *et al*. 1990; Turrini *et al*. 1991). Three main groups of foods were considered: cereals (pasta, rice, bread and bread products, and pastries), potatoes, legumes. Different commercial brands for each sample were purchased, according to the known presence on the market. Samples were prepared 'as eaten' and submitted to simulated chewing, followed by total and resistant starch determination using the enzymic procedure published as a result of the EC Concerted Action EURESTA (Champ, 1992). From these results, the estimated average intake of RS in Italy was found to be 8·5 g/d, with regional differences (from 7·2 g/d in the north-west to 9·2 g/d in the south) mainly due to the different consumption of some typical Italian starchy food (bread, pasta, legumes).

Resistant starch: Italian diet

Resistant starch (RS) has been defined as the starch fraction in foods which is highly resistant to digestion by pancreatic amylase (*EC* 3.2.1.1; Englyst *et al*. 1982). This analytical definition is often coupled with a physiological definition, i.e. 'the sum of starch and starch-degradation products that reach the human large intestine' (Champ, 1994). The characteristics of RS are similar to those of insoluble fibres, since it does not affect postprandial insulin, glucose and free fatty acid response after a glucose load (Ranganathan *et al*. 1994) and, once in the colon, it moderately increases stool weight (Cummings *et al*. 1996). However, like soluble fibre, RS is a substrate for microbial fermentation, giving origin to endproducts, mainly short-chain fatty acids, and influencing lipid and N metabolism in human and animal studies (Cummings & MacFarlane, 1991; De Deckere *et al*. 1993, 1995; Morand *et al*. 1994; Phillips *et al*. 1995; Younes *et al*. 1995 *a,b*). A particularity of RS is that its fermentation generates high levels of butyric acid compared with other fermentable carbohydrates (Englyst & MacFarlane, 1986; Scheppach *et al*. 1988). Butyrate is an important substrate for the colonocyte, and appears to be of special relevance in relation to the welfare of the epithelium of the colon. Deficiency of luminal butyrate leads to an energy-deficient state for the colonocyte, and thus to atrophy of the mucosa (Roedinger, 1990). Moreover, butyrate is a potent inducer of differentiation of tumour cells (Whitehead *et al*. 1986), and it is able to slow down proliferation in a number of colo-rectal cancer cell lines, possibly by arresting cells in the G1 phase of the cell cycle (Barnard & Warwick, 1992). A possible relevance of RS for colonic cancer prevention is suggested by experimental human studies. It has been demonstrated that RS reduces mucosal proliferation in rectal biopsies (Van Munster *et al*. 1994), a biomarker of cancer risk, probably by interfering with bile acids metabo-lism (Verbeek *et al*. 1995), and that it reduces bacterial β-glucosidase (*EC* 3.2.1.21) activity and faecal concentration of secondary bile acids, neutral sterols and sterol metabo-lites (Hylla *et al*. 1998), all factors related to cancer risk. Cassidy *et al*. (1994) found a significant and inverse relationship between the incidence of colon cancer and dietary intake of starch in a cross-country observational

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Table 1. Types and characteristics of the foods analysed

Main group	Sub-group	Categories	
		Ingredients or variety	Processing
Cereals	Pasta	Durum wheat, eggs	Industrial or home-made drying, surface area
	Rice	S. Andrea, Padano, Originario, Arborio, Carnaroli	Different recipes with low or high water availability during cooking
	Bread products	White flour, wholemeal flour, oil	Yeast-leavened or sourdough-fermented
	Pastries		Different recipes, different degree of gelatinization of starch in the product
Potatoes	Potatoes	White or yellow	Low or high water availability during cooking
	Dumplings	Wheat flour	Cooling and reheating
Legumes		Peas, lentils, beans, chickpeas*	Frozen, dried, canned

* *Pisum sativum*, *Lens esculenta*, *Phaseolus vulgaris*, *Cicer arietinum* respectively.

study, suggesting that, together with NSP, RS present in normal human diets could contribute to the protection against colo-rectal cancer.

Although RS naturally occurs in cereals and vegetables, generally encapsulated within plant cells or tissue structures, most of the RS in the diet is present as a result of food processing (Muir *et al.* 1995). The formation of RS in food processing seems to be related in particular to the amylose content, to water availability and to starch–lipid interaction (Bravo *et al.* 1994; Eerlingen *et al.* 1994).

The heterogeneity of starchy foods, together with methodological considerations, is a major problem in the evaluation of the amount of RS in the human diets.

Early estimations of RS, considered as the starch escaping digestion, were derived in individual foods or in controlled experimental diets either directly by analysis of starch output in ileostomy effluents (Englyst & Cummings, 1985, 1987; Muir *et al.* 1995; Silvester *et al.* 1995) and ileal intubation of healthy volunteers (Stephen *et al.* 1983; Faisant *et al.* 1995), or indirectly by breath H_2 measurements (Wolever *et al.* 1986a; Levitt *et al.* 1987). Results vary, in relation to the method used and to the food investigated, from a minimum value of 3–4 % of the total starch (TS) intake to a maximum of 10–20 % of the TS intake. On the other hand, analysis of food items using *in vitro* methods, such as those proposed by Englyst *et al.* (1992) and Champ (1992), once applied to food consumption data obtained from national surveys, gave an indirect estimation of 4 g/d as the average RS intake in Europe (Dysseler & Hoffem, 1994a).

Since, to our knowledge, no values exist regarding RS intake in Italy, we analysed the RS content in a range of food, representing the major contributors of starch in the Italian diet, then we used the results to estimate the daily RS intake on the basis of Italian food consumption data.

Methods

Sample selection

Food selection was based on information published by the National Institute of Nutrition (INN) about food consumption in Italy (Saba *et al.* 1990; Turrini *et al.* 1991). The published information were also used in order to choose the

preserving technique or for recipes. The INN survey covered a sample of about 10 000 households distributed throughout the whole country. The method adopted was a mixture of a direct and indirect survey based on weight and on inventory with an open list of food items. The household consumption of foods for 1 week was calculated as the difference between amounts entered daily in the household and the quantity registered at the final inventory, minus the amounts wasted daily, given as gifts or consumed by guests. All the amounts were obtained by weighing the quantities using a scale, under the supervision of dietitians. The items and categories reported in the INN survey were adopted to select the foods to be analysed for RS content. Three main groups of foods were considered: cereals, potatoes and legumes. In each group, different characteristics and processing conditions of food products were considered (Table 1).

Among cereals, foods were further divided into four sub-groups: pasta, rice, breads, pastries. The pasta sub-group was divided into three categories: short and long dry pastas and egg pasta. For all pasta products, items from three leading companies (two industrial, one semi-industrial), covering about 55 % of the national market, were purchased from supermarkets. For each category, analytical values of different brands were averaged.

Five varieties of rice, covering about 80 % of varieties commonly consumed in Italy were chosen, and purchased from supermarkets.

The bread sub-group was divided into two categories: bread and bread products. Bread was further divided into sourdough-leavened, yeast-leavened, wholemeal, 'oil' bread and pizza. Bread products were breadsticks, white and wholemeal crispbread, white and wholemeal crackers. Products from different brands were purchased either from supermarkets or (in the case of fresh bread) from local bakery stores.

Pastries were divided into semi-sweet biscuits, short-sweet biscuits and artificially-leavened cakes. For each category, a range of products of different brands were purchased from supermarkets and bakery stores, then pooled and analysed.

The potato group was divided further into yellow and white potatoes. For each type of potato, two different cooking procedures were adopted: boiling in salted water

or roasting. White potatoes were also analysed as potato dumplings. All products were purchased from local markets in the autumn and winter periods.

The legume group was divided into beans (*Phaseolus vulgaris*), peas (*Pisum sativum*), lentils (*Lens esculenta*) and chickpeas (*Cicer arietinum*). Two different varieties of beans were obtained, Romano beans and White beans. All products were further divided into dry, canned and (for beans and peas) frozen products. For each legume, different brands of canned and frozen products were purchased from local supermarkets; dried legumes were purchased from a local grocery store. Analytical values for the different variety of beans were averaged.

Sample preparation and analysis

Samples were analysed 'as eaten'. Products directly edible (i.e. breads, bread products and pastries) were minced in a Waring blender. Products normally eaten after boiling, such as pasta, potatoes and legumes, were boiled in salted water (50 g NaCl/l) following cooking instructions on the packets. Dried legumes were re-hydrated for 12 h before cooking. Rice was cooked according to two different recipes, boiling in salted water and pan-cooking (risotto). Risotto is a typical recipe in Northern Italy, consisting of gradual addition of water during cooking so that no starch is lost in the cooking liquid. Roasted potatoes were peeled, cut into quarters and baked using a thermo-convection oven at 250° for 20 min.

All samples were analysed for moisture, TS and RS. TS and RS were determined using the enzymic procedure proposed by Champ (1992), modified by introducing a simulated chewing step for the analysis of moist foods. To this purpose, just after cooking, warm samples were forced through a 1·5 mm steel sieve by means of a glass pestle. Sample portions of the extruded moist food or of the minced dry food, calculated to contain about 100 mg starch, were then dispersed in 0·1 M-Tris maleate buffer, hydrolysed for 16 h with pancreatic α-amylase, extracted with ethanol (800 ml/l), and the dry residues redispersed in 2M-KOH and hydrolysed with amyloglucosidase (*EC* 3.2.1.3). Free glucose was then analysed using a glucose analyser (YSI 2300; Yellow Spring Instruments, Yellow Spring, OH, USA) and reported in polymeric form to calculate RS. Results obtained as described were used to evaluate the mean daily RS intake for the Italian population.

For this purpose, consumption values for starchy foods obtained in the INN survey were used. The RS values for individual foods or food categories or sub-groups were used in order to match as close as possible all food categories reported in the survey. The amounts of foods considered to represent intake were recalculated on a dry weight basis and, using TS and RS contents derived from analysis, daily TS and RS intakes were calculated.

Statistical analysis

Values are expressed on dry weight basis as means with their standard errors. Values were subjected to one-way ANOVA and differences among products were checked by post hoc Tukey HSD test.

Table 2. Resistant starch (RS) in the main food groups in the Italian diet*

(Mean values with their standard errors for the no. of determinations indicated)

	RS (g/kg dry wt)		
	Mean	SE	n
Cereals	32·2[a]	1·6	100
Potatoes	56·7[b]	2·5	22
Legumes	116·8[c]	3·9	41

[a,b,c] Mean values in the same column not sharing a common superscript letter were significantly different (*P* < 0·05).
* For details of procedures, see p. 334.

Results

Resistant starch content of foods

The mean RS values for the three main food groups are shown in Table 2. In general, the foods which are most frequently consumed in Italy contain different levels of RS; on dry weight basis, cereals showed the lower, potatoes the medium and legumes the higher RS content.

Table 3 reports the mean RS values for the four sub-groups of cereal foods. Tables 4–7 report the mean RS values, differentiated by the variety or processing conditions, for each food item.

Among pasta products (Table 4), egg noodles showed a significantly (*P* < 0·05) higher content of RS.

For rice products (Table 5), the variety significantly affected the RS content of boiled products; on the other-hand, there were no differences in the RS contents among varieties for the pan-cooked rice. Also, the RS contents of two varieties (i.e. Originario and S. Andrea) were significantly affected by cooking conditions.

Among bread products, pizza and sourdough bread showed the highest RS content, similar to those observed in white and wholemeal crispbreads (Table 6).

In pastries, artificially-leavened cakes showed a significantly (*P* < 0·05) lower RS content than biscuits (Table 7). The RS contents of the biscuits were not affected by the composition or processing.

For potatoes (Table 8), neither variety nor home processing (i.e. boiling in salted water, oven roasting or dumpling preparation) produced significantly different levels of RS.

No differences in RS content were found between legume varieties (Table 9). The techniques of preservation had a

Table 3. Resistant starch (RS) in cereal foods in the Italian diet*

(Mean values with their standard errors for the no. of determinations indicated)

	RS (g/kg dry wt)		
	Mean	SE	n
Pasta	37·1[a]	3·3	9
Rice	50·9[b]	2·0	30
Bread	21·7[cd]	1·3	52
Pastries	22·3[d]	3·7	9

[a,b,c,d] Mean values in the same column not sharing a common superscript letter were significantly different (*P* < 0·05).
* For details of procedures, see p. 334.

Table 4. Resistant starch (RS) in pasta in the Italian diet*

(Mean values with their standard errors for three determinations)

	RS (g/kg dry wt)	
	Mean	SE
Egg noodles	49·1[a]	6·8
Spaghetti	28·4[b]	2·6
Short pasta	33·9[ab]	3·5

[a,b] Mean values in the same column not sharing a common superscript letter were significantly different ($P < 0.05$).
* For details of procedures, see p. 334.

significant ($P < 0.05$) effect on RS levels only for beans and peas, the highest values being found in the canned product.

Resistant starch intake in Italy in the 1980–4 period

Table 10 reports values for consumption of different foods containing starch, based on the INN food consumption survey (Saba *et al.* 1990; Turrini *et al.* 1991), and the calculated average daily intake of TS and RS. The estimated mean value for RS intake for Italy of 8·5 g/d represented about 4 % of the daily TS intake.

Fig. 1 shows the estimated daily intake of RS for the four main areas of Italy and the percentage of RS provided by the different foods considered. There was a geographical trend in RS consumption from northern to southern Italian regions.

Bread and pasta were the major sources of RS in all the areas, providing approximately 60 % of the total amount of RS, followed by legumes in central and southern regions and by rice in northern areas (about 13 and 14 % respectively).

Discussion

Despite the rise of interest in recent years concerning the potential of RS in improving human health, surprisingly little information is available on the presence of RS in foods

Table 5. Resistant starch (RS) in boiled and pan-cooked varieties of rice in the Italian diet†

(Mean values with their standard errors for three determinations, except all varieties with fifteen determinations)

	RS (g/kg dry wt)			
	Boiled		Pan-cooked	
Variety	Mean	SE	Mean	SE
All varieties	52·2	3·8	49·6	1·3
Padano	51·0[ac]	3·1	55·6	1·9
Originario	70·4[b]	6·6	47·1*	2·0
S. Andrea	66·1[bc]	0·5	47·0*	0·4
Arborio	44·2[a]	1·7	49·7	3·8
Carnaroli	39·5[a]	2·5	49·1	1·5

[a,b,c] Mean values in the same column not sharing a common superscript letter were significantly different ($P < 0.05$).
Mean values were significantly different from those for the same variety boiled:
  *$P < 0.05$.
† For details of procedures, see p. 334.

Table 6. Resistant starch (RS) in bread products in the Italian diet*

(Mean values with their standard errors for the no. of determinations indicated)

	RS (g/kg dry wt)		
	Mean	SE	*n*
Sourdough bread	32·3[acd]	3·4	6
Yeast-leavened bread	18·6[bd]	2·8	6
Wholemeal bread	20·8[d]	3·2	6
'Oil' bread	11·1[bd]	2·1	6
Pizza	39·5[c]	3·0	3
Crackers	18·4[acd]	0·8	12
Wholemeal crackers	13·1[c]	0·5	3
Breadsticks	24·1[d]	4·0	4
Crispbread	30·8[bd]	0·5	3
Wholemeal crispbread	30·9[bd]	1·6	3

[a,b,c,d] Mean values in the same column not sharing a common superscript letter were significantly different ($P < 0.05$).
* For details of procedures, see p. 334.

and on its intake in the diet. This could be due to: (1) the fact that RS is actually the sum of different starch fractions which can resist digestion in the upper gastrointestinal tract, and that in foods a wide heterogeneity of RS can be expected, related to ingredients, industrial and domestic processes; (2) the limits of analytical procedures employed to evaluate RS.

The first procedure described to determine RS (Englyst *et al.* 1982) included milling and boiling, and was thus capable of estimating only the retrograded amylose fraction (RS3) present in foods. The modified procedure introduced by Berry (1986) avoided the boiling step, hence making it possible to estimate also the native B-type starch fraction (RS2). This method was further modified by Champ (1992), by eliminating the pullulanase (*EC* 3.2.1.41) hydrolysis step, and was submitted to an interlaboratory evaluation in the framework of the EC Concerted Action EURESTA. However, in this procedure, the samples are usually dried and milled before analysis, thus preventing the determination of the fraction of starch which is resistant as a consequence of encapsulation in the food structure (RS1). Moreover, the most-commonly-adopted procedures for sample preparation (i.e. air-drying, freeze-drying) are likely to produce artefacts in the RS3 fraction, since the samples are cooled, heated, or frozen, thus potentially affecting starch retrogradation.

In the present work, we wanted to analyse RS as the sum

Table 7. Resistant starch (RS) in pastries in the Italian diet*

(Mean values with their standard errors for three determinations)

	RS (g/kg dry wt)	
	Mean	SE
Semi-sweet biscuits	28·6[a]	1·0
Short-sweet biscuits	27·4[a]	1·6
Artificially-leavened cakes	10·8[b]	1·4

[a,b] Mean values in the same column not sharing a common superscript letter were significantly different ($P < 0.05$).
* For details of procedures, see p. 334.

Table 8. Resistant starch (RS) in different types of potato after different cooking procedures in the Italian diet*

(Mean values with their standard errors for the no. of determinations indicated)

	RS (g/kg dry wt)											
	All recipes			Boiled			Baked			Dumplings		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
White	53·4	2·0	13	48·8	3·9	4	56·5	2·4	5	54·7	4·5	4
Yellow	60·8	4·7	9	65·6	4·6	4	57·0	7·7	5			

of all RS types present in different foods as they are normally consumed (i.e. cooked or raw, warm or cold, moist or dry). To this purpose, we adopted Champ's (1992) procedure but, in the sample preparation, we avoided treatments such as drying, milling and cooling, to eliminate as much as possible the production of artefacts, and we introduced a simulated chewing step by extruding moist foods through a steel sieve.

Similarly, Englyst et al. (1992) introduced a simulated chewing step in his procedure, by mincing samples before incubation. Muir & O'Dea (1992), and more recently Åkerberg et al. (1998), introduced a standardized chewing step to prepare the sample for in vitro hydrolysis. All these methods have been validated against ileostomy studies conducted using the same or similar foods, and seem to give more realistic values compared with mechanical disintegration, so that it is possible to include RS2 in the analysis.

If underestimation of RS seems unlikely to have occurred in the present study due to the modifications in sample preparation with respect to the original procedure, a certain degree of overestimation could still be present.

In fact, the analytical method employed does not include all the enzymic steps which normally occur in vivo, and thus it is possible that for foods with a tight network of protein surrounding starch granules, α-amylase access could have been impaired. Goni et al. (1996) found that including a proteolytic step in the hydrolysis procedure lowered the RS value from 19·3 to 16·3 g/kg in wheat flour and from 89 to 82 g/kg in lentil flour. We were aware of this problem but, due to the large number of samples analysed, we accepted the relatively small inaccuracy of Champ's (1992) method,

which was balanced by the higher ease of execution, better reproducibility and lower cost compared with other procedures (Dysseler & Hoffem, 1994b). Furthermore, it must be pointed out that other individual factors are not controllable in an in vitro method. The actual chewing habits, the presence of other food components within a meal (Olesen & Gudmand-Hoyer, 1997), the amount of starch consumed in a single meal or the gastrointestinal transit time (Chapman et al. 1985), or individual differences in intestinal physiology (Thornton et al. 1987) have all been demonstrated as having an effect on the amount of starch which escapes digestion. Thus, any RS database compiled on the basis of analytical methods (the present study included), should not be relied on completely to provide absolute values for individuals, although it could be useful for ranking foods, or for population studies.

Among starchy foods, cereal-based products are the most important sources of starch in the human diet, bread being the most important source of cereals. In Italy during the early 1980s, the estimated daily intake of bread ranged from 110 to 180 g/d depending on regional food habits, with a national mean of about 160 g/d, which represented more than 40 % of the total daily intake of starch. Thus, it is not surprising that RS from bread constituted a considerable proportion of RS introduced daily. The value of 2·6 g RS/d for bread estimated in the present study is similar to that calculated for the same food in Spain (Dysseler & Hoffem, 1994a), and it is about fivefold greater than the value reported for other European countries (Dysseler & Hoffem, 1994a).

In bread and similar products, RS content has been related to starch retrogradation during staling (Kulp & Ponte, 1981). A high content of RS was found by Liljeberg & Bjorck (1994) in pumpernickel rye bread made with sour-dough leavening using long fermentation and baking times. We obtained similar results in Italian sourdough bread. This product is typical of southern regions of Italy, and generally prepared with durum wheat. The presence of organic acids produced during fermentation could facilitate the formation of RS, possibly through a debranching of the amylopectin moiety during baking. It has been shown, in fact, that debranched amylopectin may form a high level of RS on heat treatments (Berry, 1986). On the contrary, the low RS levels observed in 'oil' breads, mainly consumed in the most affluent areas of the country, were unexpected, since it has

Table 9. Resistant starch (RS) in legumes processed differently in the Italian diet*

(Mean values with their standard errors for the no. of determinations indicated)

	RS g/kg dry wt											
	All processing			Dried			Canned			Frozen		
	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n
Beans†	116·0	5·3	14	99·6[b]	6·4	5	133·0[a]	1·7	5	114·2[ab]	5·7	4
Peas†	124·1	10·7	11	128·9[ab]	5·2	4	143·8[b]	1·5	3	89·7[a]	24·1	4
Lentils†	114·4	7·5	8	102·0	0·5	4	126·8	5·9	4			
Chickpeas†	109·0	8·8	8	109·4	20·2	4	108·7	7·6	4			

[a,b] Mean values in the same line not sharing a common superscript letter were significantly different ($P < 0.05$).
* For details of procedures, see p. 334.
† Phaseolus vulgaris, Pisum sativum, Lens esculenta, Cicer arietinum respectively.

Table 10. *Starchy food consumption* and estimated daily intakes of total starch (TS) and resistant starch (RS) in the Italian population*

Food	Amount (g/d)	TS (g/d)	RS (mg/d)
White bread	158·0	93·2	2608
Other breads	6·9	3·4	111
Breadsticks, crackers	6·6	4·4	131
Pasta	80·1	57·6	2489
Rice	15·2	12·0	729
Legumes; Fresh or frozen	13·9	1·4	344
Canned	7·1	0·4	257
Dried	5·0	2·3	459
Potatoes	55·3	8·8	656
Other starchy foods	62·0	31·0	742
Total		214·2	8525

* Based on the National Institute of Nutrition food consumption survey (Saba *et al.* 1990; Turrini *et al.* 1991).

been shown that starch–lipid interactions may impair starch availability to enzymic digestion (Elliason & Krog, 1985). As there is a qualitative and quantitative difference in the consumption of bread products, so the percentage of RS introduced can vary between regions by more than 10 %.

Pasta products have been reported to elicit reduced glycaemic responses (Wolever *et al.* 1986*b*; Monge *et al.* 1990), and thus to induce the metabolic advantages of low glycaemic index food (Jenkins *et al.* 1987). In addition to this potential, we found that pasta was the second main

source of RS in the Italian diet, since it contributed to the daily RS intake by a mean amount of 2·5 g/d (29 % of the total daily RS intake). Processing, with its effects on starch structure, is the main determinant of starch susceptibility to α-amylolysis in pasta (Pagani *et al.* 1986; Monge *et al.* 1990). However, the pasta surface area does not relate to the glycaemic response (Wolever *et al.* 1986*b*). Similarly, the shape of pasta does not seem important in relation to the RS if compared with the ingredients. The significantly high RS content of egg noodles might be related to the interaction between starch and protein present in eggs. However, the high RS levels in egg pasta had a limited effect on the daily RS intake, since in Italy the consumption of noodles represented only one-tenth of the total daily pasta consumption (Turrini *et al.* 1991).

In northern regions rice was the third main source of RS. In these areas rice consumption contributes about 13–16 % of the total RS intake compared with 6·5–7 % of the total RS intake in southern and central regions. The method of cooking and the variety of rice have significant effects on the RS content. Differences among varieties could be due to differences in the amylose content (amylose being one of the main determinants of RS in refined products), whereas the influence of the cooking method could derive from different amounts of starch leaking into the cooking liquid.

In central and southern regions of Italy there is less rice in the diet, with legumes making up about 12–14 % of the total daily RS intake. Moreover, in the south of Italy legumes were fresh, frozen or dried, while in the North canned
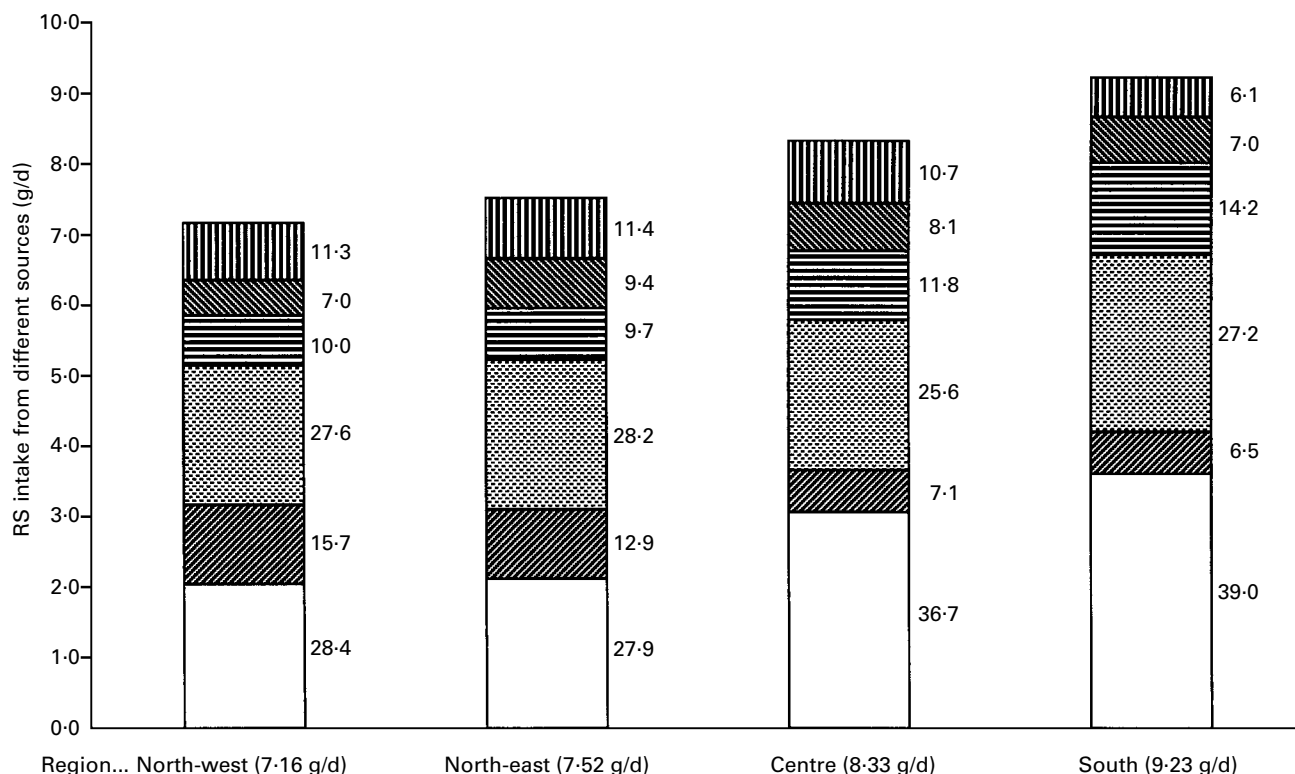

Fig. 1. Daily resistant starch (RS) consumption (g/d) and percentages of RS provided by different foods in Italian regions. (☐), Bread; (▨), rice; (▦), pasta; (▤), legumes; (▧), potatoes; (▥), others.

products were more popular (Turrini *et al.* 1991). Legumes are known to have slow starch digestibility as a consequence of both their amylose content and of their rigid cell wall matrix (Wong *et al.* 1985; Wursch *et al.* 1986), and generally their starch digestibility is enhanced by drastic high-moisture heat processing such as canning (Johansen *et al.* 1994). However, our findings of a higher RS content in canned legumes compared with frozen and dry products are not contradictory. In fact, canned products undergo a high-temperature process followed by slow cooling, which, on one hand, could decrease the RS1 fraction by cell disruption; on the other hand, it increases RS3 as a consequence of amylose retrogradation.

The daily intake of RS (8·5 g) evaluated in the present study could be considered of nutritional importance. In fact, if we consider that from INN survey the estimated fibre intake in Italy in the period considered was about 21 g/d (Saba *et al.* 1990), the concomitant consumption of 8·5 g RS/d would lead to an increase of about 50 % in the colonic load of undigested carbohydrates, thus enhancing the effects of colonic fermentation. Other studies have reported considerably lower values for RS in the diet of European countries, ranging from 3·22 g/d in Norway to 5·74 g/d in Spain (Dysseler & Hoffem, 1994*a*). This difference could reflect the large amount of starchy food (bread, pasta, rice and legumes) consumed by the Italians in the early 1980s, or simply be due to a less-complete database for the RS contents of foods available in other countries. Our database can be considered complete, as it covers more than 90 % of starch sources and more than 95 % of starch intake. Moreover, the fact that there is a strict agreement between the daily amount of TS calculated by direct analysis of the foods we used to estimate the RS intake (214·2 g/d) and the value reported by the authors of the survey using Italian food tables (212·8 g/d; Saba *et al.* 1990), testifies the correctness of our reclassification of the food sources. Moreover, the estimate that RS represents about 4 % of TS is similar, if not lower than, other estimates used in international comparisons (Cassidy *et al.* 1994). However, it is possible that dietary habits have changed in Italy over the last 15 years, so that presently the daily RS intake could be lower. This possibility seems to be supported by the trend of data on Italian food intake provided by the Central Institute of Statistics (Istituto Centrale di Statistica, 1996), using diary plus interview methodologies on a sample of 3500 households. In the period 1984–95, individual consumption of bread and pasta decreased from 71·9 to 61·5 kg/year, and from 35·2 to 31·9 kg/year respectively.

International comparison (Cassidy *et al.* 1994) revealed a strong inverse relationship between the sum of NSP and RS intake (estimated from TS intake), and colo-rectal cancer incidence. However, many factors can confound this type of relationship, including substantial genetic and environmental differences in different populations. The present study has revealed that there is a north–south gradient in RS intake which reflects differences in dietary habits between geographical areas of Italy. In this type of within-country model such knowledge and the identity of the genetic background can facilitate the study of the relationship between RS intake and the incidence of colon cancer.

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