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 10000 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 colorectal 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 metabolism (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 metabolites (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

Abbreviations: INN, National Institute of Nutrition; RS, resistant starch; RS1, starch which is resistant as a consequence of encapsulation in the food structure; RS2, native B-type starch; RS3, retrograded amylose; TS, total starch.

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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\textsubscript{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 a scale, under the supervision of dietitians. 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).

Table 1. Types and characteristics of the foods analysed

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

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

Among cereals, foods were further divided into four subgroups: 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.

Pastry 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°C 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 amylglucosidase (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.

**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 subgroups 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

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

<table>
<thead>
<tr>
<th>Food</th>
<th>Mean SE n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cereals</td>
<td>32.2 ± 6</td>
</tr>
<tr>
<td>Potatoes</td>
<td>56.7 ± 5</td>
</tr>
<tr>
<td>Legumes</td>
<td>116.8 ± 12</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Food</th>
<th>Mean SE n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasta</td>
<td>37.1 ± 3</td>
</tr>
<tr>
<td>Rice</td>
<td>50.9 ± 2</td>
</tr>
<tr>
<td>Bread</td>
<td>21.7 ± 1</td>
</tr>
<tr>
<td>Pastries</td>
<td>22.3 ± 3</td>
</tr>
</tbody>
</table>

* 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)

<table>
<thead>
<tr>
<th>Variety</th>
<th>RS (g/kg dry wt)</th>
<th>Mean</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Padano</td>
<td>51.0</td>
<td>2.8</td>
<td>3.1</td>
</tr>
<tr>
<td>Originario</td>
<td>39.5</td>
<td>4.2</td>
<td>5.6</td>
</tr>
<tr>
<td>S. Andrea</td>
<td>70.4</td>
<td>4.2</td>
<td>2.6</td>
</tr>
<tr>
<td>Carnaroli</td>
<td>33.9</td>
<td>9.0</td>
<td>3.5</td>
</tr>
</tbody>
</table>

**Notes:**
- 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.

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 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...
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 sourdough 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 amylpectin moiety during baking. It has been shown, in fact, that debranched amylpectin 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 8. Resistant starch (RS) in different types of potato after different cooking procedures in the Italian diet*

<table>
<thead>
<tr>
<th></th>
<th>RS (g/kg dry wt)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean SE n</td>
<td>Mean SE n</td>
<td>Mean SE n</td>
<td>Mean SE n</td>
</tr>
<tr>
<td></td>
<td>All recipes</td>
<td>Boiled</td>
<td>Baked</td>
<td>Dumplings</td>
</tr>
<tr>
<td>White</td>
<td>53.4 2.0 13</td>
<td>48.8 3.9</td>
<td>56.5 4.6</td>
<td>54.7 4.5</td>
</tr>
<tr>
<td>Yellow</td>
<td>60.8 4.7 9</td>
<td>65.6 4.6</td>
<td>57.0 7.7</td>
<td>54.7 4.5</td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>Legume</th>
<th>RS (g/kg dry wt)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean SE n</td>
<td>Mean SE n</td>
<td>Mean SE n</td>
<td>Mean SE n</td>
</tr>
<tr>
<td></td>
<td>All processing</td>
<td>Dried</td>
<td>Canned</td>
<td>Frozen</td>
</tr>
<tr>
<td>Beans†</td>
<td>116.0 5.3 14</td>
<td>99.6 6.4  5</td>
<td>133.0a 1.7</td>
<td>114.2ab 5.7</td>
</tr>
<tr>
<td>Peas†</td>
<td>124.1 10.7 11</td>
<td>128.9ab 5</td>
<td>143.8b 1.5</td>
<td>89.7a 24.1</td>
</tr>
<tr>
<td>Lentils†</td>
<td>114.4 7.5 8</td>
<td>102.0 0.5</td>
<td>126.8 3.9</td>
<td>89.7a 24.1</td>
</tr>
<tr>
<td>Chickpeas†</td>
<td>109.0 8.8 8</td>
<td>109.4 20.2</td>
<td>108.7 7.6</td>
<td>89.7a 24.1</td>
</tr>
</tbody>
</table>

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.
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. 1986b; 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. 1986b). 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...
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, 1994a). 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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