Phenolic compounds content and antioxidant capacity of meals provided to elementary public schools in Chile during 2011

Mariane Lutz, Romina Barraza, Carolina Henríquez

Centro de Investigación y Desarrollo de Alimentos Funcionales CIDAF, Facultad de Farmacia, Universidad de Valparaíso, Gran Bretaña 1093, Valparaíso, Chile.

SUMMARY. The Chilean National School Feeding Program (NSFP) delivers breakfast and lunch meals that supply 250 and 450 kcal, respectively, along the country. In the last decades, a significant increase of obesity has been observed in primary education children, and it involves risk factors of non-communicable diseases. The dietary intake of foods containing phenolic compounds (PC) exerts favorable effects on health by reducing risk factors of prevalent diseases. The aim of the study was to measure the PC content and antioxidant capacity (AC) [ORAC and DPPH] of meals provided by the NSFP in Quillota, Chile, in 2011. The PC supply of the whole meals served ranged from 362.7 to 1,730 mg GAE. The best breakfast foods include whole grain cookie (2.59±0.3 mg GAE/g), bread with avocado, quince jelly or strawberry jam (1.61±0.13 to 2.05±0.3 mg GAE/g); while the best lunch salads include beetroot, lettuce, and cabbage/fish (1.66±0.3 to 2.35±0.1 mg GAE/g), and main courses contain legumes, or mixed vegetables. The lowest PC contents were observed in pasta and rice preparations ($p<0.05$). Among desserts, the best source of PC is fruit (1.81±0.04 to 6.91±0.31 mg GAE/g). The correlation between PC and AC varied according to the type of meal. PC content and AC are additional criteria for selecting the best quality meals, in addition to the nutrients and energy content. The results support the recommendation to increase the supply of fruits and vegetable/legumes preparations and fruits instead of starchy foods to scholars.

Key words: School diet, antioxidants, polyphenols, feeding program, breakfast, lunch.

RESUMEN: Contenido de compuestos fenólicos y capacidad antioxidante de alimentos entregados a las escuelas públicas de enseñanza básica en Chile durante 2011. El Programa de Alimentación Escolar (PAE) para enseñanza básica en Chile distribuye, en todo el país, desayunos y almuerzos que aportan 250 y 450 kcal, respectivamente. En las últimas décadas ha aumentado significativamente la obesidad en escolares, lo que induce factores de riesgo de enfermedades no transmisibles. La ingestión de alimentos que contienen polifenoles (PF) ejerce efectos beneficiosos al reducir factores de riesgo de enfermedades prevalentes. El objetivo del estudio fue determinar el contenido de PF y la capacidad antioxidante (CA) [ORAC y DPPH] de los alimentos entregados por el PAE en Quillota, Chile, en 2011. El aporte de PF en las raciones servidas fluctuó entre 362.7 y 1,730 mg EAG. El mejor desayuno contenía galletón con granos integrales (2.59±0.3 mg EAG/g), pan con palta, dulce de membrillo o de fresas (1.61±0.13 a 2.05±0.3 mg EAG /g) y el mejor almuerzo, ensaladas de remolacha, lechuga, o col/pescado (1.66±0.3 a 2.35±0.1 mg EAG /g), y un plato principal con leguminosas o vegetales mixtos. Los contenidos menores de PF se observaron en platos con pastas y arroz ($p<0.05$). Entre los postres, la mejor fuente de PF es la fruta (1.81±0.04 a 6.91±0.31 mg EAG/g). La correlación entre PF y CA fluctuó según el tipo de preparación. El contenido de PF y la CA son criterios de calidad adicionales al aporte de energía y nutrientes de las preparaciones. Los resultados apoyan la recomendación de aumentar el aporte a los escolares de frutas y vegetales/leguminosas en lugar de alimentos con alto contenido de almidones.

Palabras clave: Alimentación escolar, antioxidantes, polifenoles, programa alimentario, desayuno, almuerzo.

INTRODUCTION

The school environment can have a large impact on children's dietary intake, because up to two meals are eaten at school every day. The Chilean National School Feeding Program (NSFP) for elementary schools delivers breakfast and lunch meals that supply 250 and 450 kcal, respectively, along the country. Breakfast includes dairy products and a cookie or sandwiches, and lunch is composed by a main course, salad and dessert. Each preparation is standardized, as well as the portion served to each child, based on a monthly basis calendar of the program. In this study we analyze the phenolic content (PC) and antioxidant capacity (AC) of the foods provided by this program during 2011, which may be considered as quality indicators of these meals.

In the last decades Chile has experimented radical changes in its bio-demographic indicators, showing a significant increase of non-communicable diseases (NCD) of multifactorial origin, which are associated with risk factors such as overweight and obesity, blood hypertension, hypercholesterolemia, and hypertriglyceridemia. These risk factors are currently affecting the young population, and the prevalence of obesity in school children is increasing at alarming rates. The Chilean diet includes a high intake of processed foods (high energy density meals, fast foods, high in saturated fats, sugars and/or sodium). The national dietary surveys exhibit an increase in the intake of meat and dairy products, and a decrease in the ingestion of fruits, vegetables, cereals and legumes. It is well recognized that fruits and vegetables have a potential for reduction of risk factors of NCD and the dietary recommendations emphasize the fact that the dietary ingestion of these and other plant derived foods should be increased.

Many NCD have a common basis in which oxidative stress is relevant, characterized by a high production of free radicals that cause cellular damage, which is not counteracted enough by the body antioxidants, including both enzymatic and non-enzymatic endogenous systems and the exogenous antioxidants provided by the diet, such as vitamins C, A, and E, as well as a wide variety of phytochemicals that include the PC (1). Modest long-term intakes of plant foods can have favorable effects on the incidence of NCD (2, 3). PC may exert their antioxidant action directly, depending on their chemical structure (3), and indirectly by inducing the expression of antioxidant enzymes (4). Inflammation is one of the risk factors that metabolically links obesity with cardiovascular diseases, and rich PC and anthocyanin-plant foods are associated with the reduction of inflammatory stress, providing protection against the development of NCD (5,6).The beneficial effects of PC intake are highly dependent on the way the body handles their absorption, metabolism and excretion. After ingestion, dietary PC appear in the circulatory system not only as the parent compounds, but mostly as phase II metabolites and/or metabolites of the colon microbiota, and their presence in plasma rarely exceeds nM concentrations (7).

There is no recommended dietary intake of PC in order to contribute to the reduction of risk factors of NCD. The dietary surveys show that the intake of fruits, vegetables, cereals, legumes, and nuts (which contain various phytochemicals, including PC) is low, and efforts should be made to improve the quality of the meals provided to elementary school children, since in this age group dietary habits are acquired. Moreover, the sound evidence of the beneficial effects of PC intake is increasing, including the mechanisms of action of these compounds via multiple signaling mechanisms which require the maintenance of optimum levels of the bioactive PC in the body tissues (8). The Chilean Dietary Guidelines, as most Guidelines around the world, do not recommend a PC content or an antioxidant capacity (AC), but a high ingestion of fruits and vegetables, cereals, legumes and nuts. There is a lack of knowledge on these values in meals, especially concerning those that are distributed by the NSFP throughout the country. Moreover, data on the PC content and AC of whole diets is limited, insufficient, and often disregarded as a quality indicator (9). The aim of this study is to evaluate the PC content and AC of the meals provided by the Chilean NSFP to children attending elementary public schools (2011) in Quillota, Chile.

MATERIALS AND METHODS

Chemicals

Folin-Ciocalteu reagent, fluorescein, acetone, and methanol were purchased from Merck (Darmstadt, Germany); gallic acid, AAPH, DPPH, and Trolox were obtained from Sigma-Aldrich (St. Louis, MO, USA).

Collection of meals

Breakfast and lunch meals provided by the NSFP were collected from 9 public primary education schools located in Quillota, Chile (Region of Valparaiso) throughout 2011. All the foods contained in 22 different meals provided by the NSFP were collected directly from the trays served to the children at the cafeteria. Samples were placed in plastic bags, sealed, and transported at 0-4°C to the laboratory, where they were homogenized using a Moulinex kitchen appliance, separated into two containers and kept at -20°C before analyses. The collected meals were thawed and homogenized and aliquots were taken to perform the chemical analysis.

Chemical assays

Total Phenolic Compounds PC was determined by the Folin-Ciocalteu assay (10), in which a blue molybdenum-tungsten complex is formed, and the intensity is proportional to the PC concentration. The method was adjusted to use a microplate reader (Synergy Multidetection HT, Biotek). A gallic acid standard solution series was prepared ranging from 235 to 1,180 µmol/L. Extracts of the samples were obtained using acetone/water (7:3). From each standard solution and sample 50 µL were mixed with 2.5 mL of Folin-Ciocalteu reagent and 2.0 mL of sodium carbonate solution. The samples were mixed and incubated at 20°C for 30 min and absorbance was read at 760 nm. The results were expressed as milligrams of gallic acid equivalents (GAE)/gram (mg GAE/g).

Antioxidant capacity (AC) For this determination, extracts of the samples were obtained using methanol/water (8:2), and the assays were adapted for the microplate reader used (Synergy Multidetection HT, Biotek).

DPPH: was performed as described by Brand-Williams et al. (11), based on the presence of the radical DPPH*, which is purple and decolorizes in the presence of antioxidants that stabilize it. Absorption is measured at 517 nm. Results are expressed as micromoles of Trolox equivalents (TE)/gram (µmol TE/g).

ORAC: was performed as described by Ou et al. (12) and Cao et al. (13), in which the radicals generated from APPH react with fluorescein. As a result, the fluorescence of the probe decreases in time and the decay kinetics can be measured. The reaction is followed by reading every min, for 90 min, at 485 nm (excitation) and 528 nm (emission). Results are expressed as micromoles of Trolox equivalents (TE)/gram (µmol TE/g).

Statistical analysis

The data are reported as mean and standard deviation of three extractions, each measured in triplicates for PC, DPPH and ORAC. Data were analyzed by analysis of variance (ANOVA) at $p<0.05$, using the SAS® program and the Tukey test was applied for comparison among the same type of meals.

RESULTS

Breakfast foods included a beverage (artificially flavored skim milk or yoghurt) and a cookie or sandwich made with white bread. Table 1 shows the PC content in breakfast meals. PC were analyzed in solid foods only, since dairy products are not source of PC. The highest PC content was observed in the cookie ($p<0.05$). Among sandwiches, bread and quince jelly, strawberry jam and avocado pulp had more PC than the varieties containing animal foods or margarine. Again, the cookie exhibited the highest AC compared with the sandwiches ($p<0.05$). ORAC ranged from 14.24 to 69.32 µmol TE/g ($p<0.05$) and DPPH varied between 7.66 and 44.76 µmol TE/g ($p<0.05$).

In lunch meals, the PC content of salads (Table 2) ranged from 0.63 to 2.35 mg GAE/g ($p<0.05$). Beetroot salad exhibited the highest PC content, followed by cabbage/tuna fish and lettuce/fish/onion, while the lowest value was observed in cabbage served alone. DPPH varied from 16.47 to 94.11 µmol TE/g ($p<0.05$), and in this case lettuce/fish/onion occupied the first place in the ranking of AC,

TABLE 1. Phenolic compounds content and antioxidant capacity of breakfast foods provided by the elementary school feeding program in Quillota, Chile, 2011.

Food	PC[1]	ORAC	DPPH
Cookie	2.59±0.3	69.32±2.2	44.76±4.7
Bread/quince jelly	2.05±0.3[a]	38.34±5.2[b]	30.80±1.2[a]
Bread/strawberry jam	1.76±0.1[ab]	32.66±4.2[b]	33.04±3.3[a]
Bread/avocado	1.61±0.13[abc]	35.58±2.8[b]	34.34±0.9[a]
Bread/dulce de leche	1.48±0.23[bcd]	50.97±1.6[a]	10.25±1.5[c]
Bread/margarine	1.17±0.08[cde]	14.24±1.8[c]	20.84±2.5[b]
Cereal	1.05±0.13[def]	39.99±0.9[b]	33.67±1.7[a]
Bread	0.94±0.06[ef]	17.13±1.8[c]	7.66±2.4[c]
Bread/pork pate	0.86±0.13[ef]	21.82±1.1[c]	10.00±1.5[c]
Bread/egg	0.66±0.02[f]	65.61±3.4	21.59±1.0[b]

[1]PC = phenolic compounds; values are presented as mg GAE/g. Antioxidant capacity ORAC and DPPH: values are presented as µmol TE/g. (n=3). Significance testing among the different samples was performed by one-way ANOVA followed by Tukey's test. Mean+SD values followed by different letters in a column are significantly different at $p<0.05$.

TABLE 2. Phenolic compounds content and antioxidant capacity of lunch salads provided by the elementary school feeding program in Quillota (Chile), 2011.

Salad	PC[1]	ORAC	DPPH
Beet	2.35±0.1	157.48±6.9	69.05±2.3^{ab}
Cabbage/tuna fish	2.16±0.1	98.90±7.8^{ab}	85.94±3.1
Lettuce/ fish/onion	1.66±0.3^{a}	112.74±0.5^{a}	94.11±6.7
Tomato/onion	1.51±0.1^{ab}	29.40±6.6^{ef}	67.83±2.5^{ab}
Potato/onion	1.48±0.1^{ab}	61.47±4.1^{c}	28.36±5.4^{c}
Tomato/egg	1.32±0.2^{abc}	37.92±6.6^{de}	16.47±0.6^{d}
Egg/carrot	1.21±0.2^{bcd}	19.53±5.9^{f}	59.83±5.5^{b}
Lettuce/tuna fish	1.07±0.1^{cd}	94.80±6.9^{b}	73.52±5.0^{a}
Potato/carrot	1.15±0.1^{cde}	47.87±2.4^{cd}	62.50±2.4^{ab}
Cabbage/carrot	0.92±0.1^{def}	16.23±4.5^{f}	67.43±3.9^{ab}
Cabbage	0.63±0.1^{e}	13.20±1.8^{f}	69.15±2.7^{ab}

[1]PC = phenolic compounds; values are presented as mg GAE/g. Antioxidant capacity ORAC and DPPH: values are presented as µmol TE/g. (n=3). Significance testing among the different samples was performed by one-way ANOVA followed by Tukey's test. Mean+SD values followed by different letters in a column are significantly different at p<0.05.

TABLE 3. Phenolic compounds content and antioxidant capacity of lunch main courses provided by the elementary school feeding program in Quillota, Chile, in 2011.

Main course	PC[1]	ORAC	DPPH
Lentils	2.03±0.1	88.74±0.9	64.20±3.4
Potato/meat/carrot	1.69±0.01^{a}	21.78±4.7^{ef}	14.33±3.0^{de}
Charquicán (mixed vegs)	1.52±0.1^{ab}	18.94±0.3^{fg}	14.43±1.0^{de}
Beans/pasta	1.46±0.1^{abc}	63.37±1.0^{a}	63.74±1.7
Chicken stew	1.43±0.4^{abc}	33.94±2.1^{bcd}	32.14±1.4^{ab}
Potato/chicken stew	1.27±0.1^{bcd}	36.35±4.8^{b}	33.26±0.4^{a}
Menestron	1.22±0.1^{bcd}	18.40±1.4^{fg}	12.43±2.3^{e}
Peas	1.18±0.3^{bcde}	18.78±1.5^{fg}	69.99±8.9
Rice/chicken stew	1.11±0.1^{bcdef}	26.82±2.7^{de}	21.21±2.6^{cde}
Rice/fish pie	1.07±0.1^{cdef}	40.77±4.4^{b}	23.31±1.7^{bcd}
Rice/ meat stew	0.99±0.02^{def}	36.47±1.9^{b}	24.66±3.7^{abc}
Rice/fish nuggets	0.99±0.04^{def}	63.37±3.3^{a}	19.15±1.3^{cde}
Potato pie/meat	0.99±0.1^{def}	3.15±0.7^{h}	14.42±1.3^{de}
Pasta 1/carrot/egg	0.89±0.03^{defg}	24.56±2.4^{ef}	24.53±2.0^{abc}
Rice/ beef streak	0.76±0.02^{fg}	11.90±0.4^{g}	2.53±0.4^{f}
Potato/pork steak	0.71±0.1^{fg}	13.77±1.5^{g}	21.64±2.4^{cde}
Pasta 2/carrot/egg	0.54±0.04^{g}	34.15±2.0^{bc}	21.95±3.7^{cde}
Pasta 3/carrot/egg	0.54±0.05^{g}	27.86±1.4^{cde}	22.76±3.4^{bcd}

[1]PC = phenolic compounds; values are presented as mg GAE/g. Antioxidant capacity ORAC and DPPH: values are presented as µmol TE/g. Pasta 1, 2, and 3 indicate different types of pasta (n=3). Significance testing among the different samples was performed by one-way ANOVA followed by Tukey's test. Mean+SD values followed by different letters in a column are significantly different at p<0.05.

followed by cabbage/tuna fish, cabbage, and beetroot salad. Table 3 shows that, among main courses, legumes exhibited the highest PC content, leaded by lentils, that differed from all the other food preparations ($p<0.05$). Table 4 shows that the PC content of desserts ranged from 0.89 to 6.91 mg GAE/g ($p<0.05$). The highest PC amount was found in green apple ($p<0.05$), followed by red apple, canned peach, orange and mote (wheat grain boiled and removed from its husk) with fruits, while the lower values were found for milk based desserts. Varied AC were also observed in desserts, with ORAC values ranging from 0 to 210.07 µmol TE/g ($p<0.05$). The highest ORAC was observed in orange, followed by apples, and mote with fruits. On the other hand, DPPH varied from 5.88 to 72.81 µmol TE/g ($p<0.05$). Canned peach had the highest DPPH value, followed by apples and orange.

Taking into account the PC content of the 22 meals analyzed, the lowest PC level was observed in the meal composed by milk + bread/ egg for breakfast, and rice/fish nuggets + grits/milk/flavored sauce for lunch (362.7 mg GAE), while the meal composed by milk + bread/avocado for breakfast and potato pie/meat + tomato/egg and green apple for lunch, presented the highest PC level (1,730 mg GAE), exhibiting significant variations on a daily basis.

The correlations between PC and AC are shown in Table 5. The highest correlation between PC and ORAC (r=0.76) was observed in salads, although it was lower in fruits (r=0.41), main courses (r= 0.44), and was not significant in breakfast sandwiches. On the other hand, no significant correlation was observed between PC and DPPH in salads, and it was low in main dishes (r=0.41), while low correlations between ORAC and DPPH were observed in salads (r=0.36) and fruits (r=0.61).

TABLE 4. Phenolic compounds content and antioxidant capacity of lunch desserts provided by the elementary school feeding program in Quillota, Chile, in 2011.

Main course	PC[1]	ORAC	DPPH
Green apple	6.91±0.31	99.39±0.63[a]	69.24±7.09
Red apple	4.37±0.77[a]	75.42±4.10[b]	65.52±5.36
Canned peach	2.42±0.08[b]	31.87±5.08[d]	72.81±3.54
Orange	1.91±0.2b[c]	210.07±5.81	64.68±0.92
Wheat mote/fruits	1.81±0.04[bc]	47.01±1.47[b]	25.71±5.96[ab]
Jelly/apple	1.71±0.02[bcd]	1.05±0.57[f]	20.01±1.21[ab]
Jelly	1.67±0.07[bcde]	ND	5.88±3.38[c]
Wheat mote/dry plum	1.36±0.11[cde]	46.80±8.94[c]	31.87±4.07[a]
Grits/milk/flavored sauce	1.27±0.20[cde]	13.41±2.82[e]	17.60±6.15[bc]
Pudding/flavored sauce	1.13±0.05[de]	7.20±1.04[ef]	27.84±4.35[ab]
Grits/milk	1.08±0.16[e]	5.42±1.31[ef]	30.78±1.17[a]
Rice/milk	0.89±0.08[e]	3.84±1.72[ef]	16.45±3.60[bc]

[1]PC = phenolic compounds; values are presented as mg GAE/g. Antioxidant capacity ORAC and DPPH: values are presented as μmol TE/g. ND: not detected. (n=3). Significance testing among the different samples was performed by one-way ANOVA followed by Tukey's test. Mean+SD values followed by different letters in a column are significantly different at $p<0.05$.

TABLE 5. Correlation coefficients between phenolic compounds content and antioxidant capacity (DPPH and ORAC) in meals provided by the elementary school feeding program in Quillota, Chile, 2011.

	Dessert		Salad		Main course		Breakfast	
	DPPH	ORAC	DPPH	ORAC	DPPH	ORAC	DPPH	ORAC
PC1	0.66*	0.41*	NS	0.76*	0.41*	0.44*	0.69*	NS
DPPH	1	0.67*	1	0.36*	1	0.57*	1	0.63*
ORAC		1		1		1		1

[1]PC = phenolic compounds. Asterisks represent that the correlation coefficient is significant ($p<0.05$). NS=not significant.

DISCUSSION

There is a lack of information on the PC content and AC of institutional meals consumed by children at school, and this study provides useful data that may be used as quality parameters of the meals provided by the NSFP that can potentially protect children's health.

In breakfast meals, the highest PC content observed in the cookie ($p<0.05$) is attributed to its ingredients: whole wheat flour and crushed oats. Among sandwiches, bread containing vegetable ingredients such as quince jelly, strawberry jam, and avocado pulp exhibited higher PC content than those containing animal ingredients or margarine. High AC (ORAC values) were found in sandwiches containing egg or cooked condensed milk ("dulce de leche"), which is attributed to the low specificity of the assay (14).

Beetroot salad exhibited the highest PC content, which is in agreement with the ranking that includes it among the 10 vegetables with higher AC (15), due to its high content of betalains. In the case of salads containing fish, the high PC content may be overestimated due to proteins that react with the Folin Ciocalteu solution. Both the beetroot and the cabbage salads served were cooked, which affects both the PC content and AC, and the values are not comparable to those in raw foods. Lettuce/fish/onion had a high AC, while boiled cabbage showed the lowest PC content and a low AC according to ORAC, occupying the last place in the ranking among salads, although it showed higher DPPH, which puts into evidence the importance of using complementary AC assays (16). Cabbage contains antioxidants such as glucosinolates and PC (17), which were probably diminished by the thermal treatment in boiling water. Salads containing potato had 1.15 and 1.48 mg GAE/g (potato/onion and potato/carrot, respectively). Although not a good source of PC, it has been reported that the PC content is higher if these tubers are cooked with peel (18).

The amount of PC is highly dependent on the cooking procedures, and PC in beans may be lost in the soaking water before cooking. It is noteworthy that the bean/pasta preparation (a very good protein combination) had a high amount of PC (1.46 mg GAE/g), which makes a difference respect to other dishes containing pasta (mainly with egg), which are among the main courses with the lower PC content, although part of the PC are reduced during cooking, such as ferulic and caffeic acids. The AC measured by DPPH, was higher in peas, followed by lentils and beans/pasta. Among the dishes showing high AC is charquican, a vegetable/meat stew that contains corn, tomato, peas, onion, carrot, sweet pepper, potato and minced meat. Potato pie also exhibited high AC, due to the presence of onion, carrot, minced meat, hard-boiled egg and raisins.

The high PC amount of green apple is well recognized, and the Chilean Antioxidants Database reports 2.39 mg GAE/g for this fruit, while other authors have reported higher PC content in Red Delicious red apple (19) and the USDA flavonoids database reports 16.08 mg/100 g in Red Delicious and 12.48 mg/100 g in Granny Smith apples. It is important to consider that the concentration of phytochemicals in food plants is highly dependent on many factors, such as cultivar, harvest, storage, processing, and the culinary techniques used (20).

The PC content of dairy desserts and jelly are negligible, and the values observed may be overestimated since the Folin Ciocalteu assay lacks specificity. The chemicals may not only react with PC but also with non-phenolic substances, including vitamin C, fructose, glucose, aminoacids, among others (21). The AC observed was higher in green apple compared with red apple and, as already described, the differences among values reported in the literature are attributable to the varieties, agro-climatic conditions, processing, among other factors. On the other hand, the presence of apple in jelly had a significant effect on the PC content and AC in this dessert, which lacks phytochemicals when served alone. The AC (ORAC and DPPH) measured in dairy desserts and jellies were significantly lower than those of fruits ($p<0.05$). However, Halvorsen et al. (22) measured the AC of some dairy desserts using the FRAP assay, obtaining values higher than those of fruits, vegetables, and cereals.

The AC of all foods and preparations is affected by synergistic, antagonistic or neutral interactions among their constituents, which does not allow the addition of the specific AC values of each ingredient used. Consequently, the AC obtained in this study may be higher or lower than the individual AC of the ingredients, and should be regarded as a reference figure for comparison only.

Both ORAC and DPPH assays are based on redox mechanisms and a correlation between them may be expected (23). The AC is affected by the presence of non-phenolic species that participate in the reactions, including antioxidant vitamins and/or their synergism with PC, contributing as a whole to the AC measured (24). Consequently, the correlations observed indicate that the AC of foods is not due to the presence of PC solely. Kevers et al. (25) observed a high correlation between PC and DPPH ($r=0.94$) in fruits and vegetables, while the correlation between PC and ORAC was lower ($r=0.61$). In Chilean grapes, Lutz et al. (23) published a high correlation between PC and ORAC ($r=0.91$), PC and DPPH ($r=0.76$).

Table 6 shows the mean contribution of all breakfast and lunch meals served in terms of PC and antioxidant capacity, as well as the range observed.

TABLE 6. Mean contribution of phenolic compounds and antioxidant capacity (ORAC and DPPH) of meals provided for breakfast and lunch in the school feeding program in Quillota, Chile, 2011.

	PC[1]	ORAC	DPPH
Breakfast	1.42 (0.71 – 2.77)	38.57 (12.96- 68.85)	24.70 (5.71- 48.10)
Total breakfast	1.42	38.57	24.70
Salad	1.41 (0.58 – 2.44)	62.70 (11.1 - 165.4)	63.11 (15.77 – 101.00)
Main course	1.12 (0.49 – 2.14)	32.00 (2.63 – 89.61)	27.82 (2.12 – 80.32)
Dessert	2.26 (0.84 – 7.16)	49.04 (0.53 - 214.17)	37.37 (5.02 – 75.62)
Total lunch	4.79	143.74	128.30
TOTAL	6.21	182.31	153.00

[1]PC = phenolic compounds; values are presented as mg GAE/g. Antioxidant capacity ORAC and DPPH: values are presented as μmol TE/g.

Lunch meals are the main contributors of PC and antioxidant capacity, supplying 77.1% of the PC, as well as nearly 80% the antioxidant capacity of the meals (78.8% ORAC and 83.9% DPPH, respectively). Among the foods contained in lunch, dessert was the main supplier of PC (mainly fresh fruit), while salad was the main contributor to the antioxidant capacity. These values emphasize the importance of providing fruits and vegetables in the NSFP.

CONCLUSIONS AND RECOMMENDATIONS

The meals provided by the NSFP during 2011 may be classified according to their PC content and AC as additional criteria for selecting the best quality preparations, considering these parameters in addition to their nutrients and energy content. The foods or preparations selected for breakfast are: cookie, bread/avocado, bread/quince jelly, and bread/strawberry jam; while for lunch salads, the selected preparations include beetroot, lettuce and cabbage/fish. The best quality main courses contain legumes, and/or mixed vegetable preparations, and the best desserts are fruits, fresh or canned. An outstanding issue is the frequency of deliverance of the preparations, eg the delivery of potato/pasta/rice dishes should be decreased while more vegetable/legumes preparations should be increased instead. Our results support the implementation of dietary planning strategies that take into consideration the consumption of PC. Higher PC intake may be achieved by different means, including the supply of fruits for breakfast, the delivery of bigger portions and a wider variety of salads, the inclusion of other types of fresh or dehydrated fruits, e.g. berries, well recognized as very good sources of PC and high AC, as well as the incorporation of a wider variety of main dishes prepared with mixed vegetables.

ACKNOWLEDGEMENTS

This work was supported by CONICYT, Chile, Project FONDEF D09I1222.

REFERENCES

1. Bravo L. Polyphenols: Chemistry, dietary sources, metabolism, and nutritional significance. Nutr Rev 1998, 56: 317-333.
2. Arts IC, Hollman PC. Polyphenols and disease risk in epidemiologic studies. Am J Clin Nutr 2005, 81: 317S–325S.
3. Fraga C, Galleano M, Verstraeten S, Oteiza P. Basic biochemical mechanisms behind the health benefits of polyphenols. Mol Asp Med 2010, 31: 435-445.
4. Stevenson DE, Hurst RD. Polyphenolic phytochemicals – just antioxidants or much more? Cell Mol Life Sci 2007, 64: 2900 – 2916.
5. He FJ, Nowson CA, Lucas M, MacGregor GA. Increased consumption of fruit and vegetables is related to a reduced risk of coronary heart disease: meta-analysis of cohort studies. J Hum Hypertension 2007, 21: 717–728.
6. Aggarwal BB, Sung B. The relationship between inflammation and cancer is analogous to that between fuel and fire. Oncology 2011, 25: 414–418.
7. Lutz M, Castro E, García L, Henríquez C. Bioavailability of phenolic compounds from grape juice cv Autumn Royal. J Food CyTA 2014, 12: 48-54.
8. Siriwardhana N, Kalupahana NS, Cekanovac M, LeMieux M, Greer B, Moustaid-Moussa N. Modulation of adipose tissue inflammation by bioactive food compounds. J Nutr Biochem 2013, 24: 613–623.
9. Tejeda L, Debiec M, Nilsson L, Peñarrieta JM, Alvarado JA. Chemical composition, antioxidant capacity and content of phenolic compounds in meals collected in hospitals in Bolivia and Sweden. Nutr Hosp 2012, 27:1009-1016.
10. Singleton VL, Rossi JA. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. Am J Enol Vitic 1965, 16: 144-158.
11. Brand-Williams W, Cuvelier ME, Berset C. Use of a free radical method to evaluate antioxidant activity. Food Sci Technol 1995, 28: 25-30.
12. Ou B, Hampsch-Woodill M, Prior RL. Development and validation of an improved oxygen radical absorbance capacity assay using fluorescein as the fluorescent probe. J Agric Food Chem 1998, 4: 4619-4626.
13. Cao GY, Prior RL. Comparison of different analytical methods for assessing total antioxidant capacity of human serum. Clin Chem 1998, 44: 1309-1315.
14. Prior R, Wu X, Schich K. Standardized methods for the determination of antioxidant capacity and phenolics in foods and dietary supplements. J Agric Food Chem 2005, 53: 4290-4302.
15. Halvorsen B, Holte K, Myhrstad MCW, Barikmo I, Hvattum E, Remberg SF, Wold AB, Haffner K, Baugerod H, Andersen LF, Moskaug J, Jacobs DR, Blomhoff R. A systematic screening of total antioxidants in dietary plants. J Nutr 2002, 132: 461–471.
16. Huang D, Ou B, Prior RL. The chemistry behind antioxidant capacity assays. J Agric Food Chem 2005,

53:1841–1856.

17. Kusznierewicz B, Bartoszek A, Wolskaa L, Drzewieck, J, Gorinstein S, Namiesnik J. Partial characterization of white cabbages (*Brassica oleracea var. capitata f. alba*) from different regions by glucosinolates, bioactive compounds, total antioxidant activities and proteins. LWT-Food Sci Technol 2008, 41: 1–9.
18. Reddivari L, Hale A, Miller C. Genotype, location, and year influence antioxidant activity, carotenoid content, phenolic content and composition in specialty potatoes. J Agric Food Chem 2007, 55: 8073- 8079.
19. Tsao R, Yang R, Young JC, Zhu H. Polyphenolic profiles in eight apple cultivars using high-performance liquid chromatography (HPLC). J Agric Food Chem 2003, 51: 6347-6353.
20. Lutz M, Henríquez C, Escobar M. Chemical composition and antioxidant properties of mature and baby artichokes (*Cynara scolymus L.*), raw and cooked. J Food Compos Anal 2011, 24: 49-54.
21. Singleton VL, Orthofer R, Lamuela-Raventos RM. Analysis of total phenols and other oxidation substrates and antioxidants by means of the Folin–Ciocalteu reagent. Meth Enzymol 1999, 299: 152–178.
22. Halvorsen BL, Carlsen MH, Phillip, KM, Bohn SK, Holte K, Jacobs DR Jr., Blomhoff R. Content of redox-active compounds (ie, antioxidants) in foods consumed in the United States. Am J Clin Nutr 2006, 84: 95–135.
23. Lutz M, Jorquera K, Cancino B, Ruby R, Henriquez C. Phenolics and antioxidant capacity of table grape (*Vitis vinifera L.*) cultivars grown in Chile. J Food Sci 2011, 76: C1088–C1093.
24. Velazquez DAJ, Zevallos C. Correlations of antioxidant activity against phenolic content revisited: a new approach in data analysis for food and medicinal plants. J Food Sci 2009, 74: R107-R113.
25. Kevers C, Falkowski M, Tabart J, Defraigne JO, Dommes J, Princemai, J. Evolution of antioxidant capacity during storage of selected fruits and vegetables. J Agric Food Chem 2007, 55: 8596–8603.

Recibido: 05-02-2015

Aceptado: 01-04-2015