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Preference of laboratory rats for food based on wheat grown under organic versus conventional production conditions

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ABSTRACT

There is extensive evidence that rats are able to sense toxicants and essential nutrients in their food and avoid foods that contain these substances. This ability was employed to assess whether the two major management factors soil fertility management and crop protection affected the food preferences of laboratory rats. Samples of wheat grown in 2005 and 2007 under four combinations of these management factors in the Nafferton Factorial Systems Comparison at Northumberland UK were used as experimental diets in food preference tests. In both years, the rats preferred organically fertilized wheat. The influence of organic and conventional crop protection was inconsistent. But a statistically significant interaction of soil fertility management and crop protection was observed: under organic soil fertility management there was generally no difference between the two crop protection methods but under conventional soil fertility management either the combination with organic crop protection (2005) or the fully conventional combination (2007) resulted in the most disliked food. In conclusion, the findings emphasize the role of soil fertility management for producing food of not only a quality that was preferred by rats but also for a high quality of the organic production system in general.

1. Introduction

The influence of agricultural production methods on quality aspects has been established ever since modern methods were introduced. But the increasing application of inorganic fertilizers and biocides with the predominant aim to increase yields has resulted in environmental hazards. Furthermore, it has been postulated that the exclusive focus on quantitative upgrading could jeopardize qualitative optimization [1]. Alternatively, the aim of the biodynamic production system founded by Steiner has always been to improve nutritional quality [2]. Organic agriculture was primarily introduced to counteract negative environmental effects, but qualitative aspects have gained importance ever since. As a consequence, numerous comparative quality investigations have been performed to relate agricultural applications to nutritional quality aspects such as optimized contents of health-promoting components as well as reduced value-decreasing residues [3]. With regard to these characteristics soil fertility management and plant protection methods have been identified as important parameters. The methods used for quality analyses usually concern agricultural performance and chemical composition. But regarding nutritional quality, animal feeding tests have gained increasing importance, since they include a holistic dimension surpassing laboratory techniques. Apart from long-term feeding experiments, mostly with complete diets, short-term food preference tests can be used to assess single products. This hypothesis, underlying preference tests, implies that animals are capable of choosing the food that best supports their metabolic well-being, if given the choice [4].

In this study the results are presented of food preference tests with laboratory rats using samples of differently grown wheat.

2. Materials and methods

The test wheat (var. Malacca) was produced in the Nafferton Factorial Systems Comparison (NFSC) at the University of Newcastle's Nafferton Experimental Farm, Northumberland, UK, in 2005 and 2007. We mainly report on the wheat produced in 2007 and tested, after storage, in rat experiments carried out in winter 2007 and summer 2008. The differentiating production factors were organic and conventional soil fertility management (composted manure vs. inorganic fertilizer) and crop protection applied in accordance with Soil Association standards and the British Farm Assured standards, respectively.

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Four combinations of soil fertility management and crop protection were applied: (1) organic soil fertility and crop protection management (OO), (2) organic soil fertility management and conventional crop protection (OC), (3) conventional soil fertility management and organic crop protection (CO), and (4) conventional soil fertility management and crop protection (CC). For convenience, the O and C diets (or wheat) are referred to here as organic and conventional, respectively.

The resulting wheat samples were compared in two series of food preference tests, each replicated four times. Per test, 20 male laboratory rats (Long Evans) were used, i.e., 5 rats per diet. The experimental wheat diets were presented as crackers baked with water only, for periods of four days. During the test periods the rats were kept in single Macrolon cages size IV. In between tests the animals were housed in pairs and allowed to rest for at least 10 days. The feeding rack was divided by the water bottle into a right and left section in which the experimental diets were apportioned. Food was apportioned for the full period of each test. Test food that remained was weighed every 24 h. The position of the diet was changed daily to avoid position preferences. Also basic food (conventional feed mixture T 779; Tagger Co., Graz, Austria) was apportioned into the feeding rack, but offered *ad libitum* during the whole test period to prevent any deficiency symptoms. The amount of basic food that remained was weighed at the end of each test.

The four diets were compared in a double-blind feeding experiment, using a randomized design. In each test, the diets were compared in pairs, yielding 6 possible pairs per test. Two trials were conducted, one in the winter of 2007 and one in the summer of 2008 using wheat from the same 2007 crop. The main emphasis was on the potential differentiation between the four diets but additional random replicates of pairs of the identical diet were included in the analysis.

The amounts of experimental diet eaten from each of the two sections of a feeding rack were analysed with a General Linear Model (GLM) followed by a Tukey test using Minitab, to separate means. The residuals were tested for normality and transformation of the data was not found necessary. To assess preference differences between two diets the Wilcoxon Test for pair differences (SPSSwin 16) was applied.

3. Results

The results obtained with the wheat from the 2005 harvest have been presented at the ISOFAR Conference in Modena in 2008 [5]. The results showed a significant preference for organically fertilized wheat ($p = 0.001$) whereas wheat consumption was lower when the crop had been inorganically fertilized in combination with organic crop protection. On the whole, the rats responded more clearly to differences caused by soil fertility management than by crop protection. The health status of the plants may have caused variation in wheat grain quality that was detectable by the rats, since there were strong, reproducible differences in plant health between the test diets [6].

The wheat samples of the 2007 harvest corroborated this positive outcome of organic soil fertility management.

Table 1
Total amounts eaten (g day^{-1}) by laboratory rats of diets based on organically or conventionally produced wheat.

	Crop protection		
Fertilization	Organic	Conventional	Mean[b]
Organic	104.5	87.9	96.2A
Conventional	91.2	71.0	81.1B
Mean[a]	97.8a	79.4b	

[a] Means in the same row, followed by a different lower case letter are statistically different at $p < 0.05$.
[b] Means in the same column, followed by a different capital letter are statistically different at $p < 0.05$.

3.1. Food preference tests with identical samples

In the preference tests comparing the same diet, most of the organic and little of the conventional wheat was eaten (Table 1). There were 32 measures of the diets compared with themselves. This is the smallest consistent dataset. One problem was that the rats pulled food out of the feeders and as all the food was the same colour it was impossible to distinguish the test foods. The main analysis is therefore for the total amount of food eaten. There was a signifncat effect of both health and fertility on the amount eaten ($p < 0.05$) but no interaction beween the treatments–there is an additive effect though, so that least of the totally conventional food was eaten (Table 1).

The organic food was preferred and was significantly correlated to the total amount eaten (Table 2). There was a significant negative correlation between the amount of this food and total food eaten and the amount of base food consumed. Clearly the rats were replacing the foods that they liked less with the base food; the amounts of the base food eaten (Table 3) follows the opposite pattern to that of the other foods eaten (Table 1). There is a significant difference ($p < 0.01$) for the health treatment but not for the fertility management. The weight development of the rats during the 4 test days might also be influenced by differences in individual adaptation to the test situation.

3.1.1. Food preference tests with different samples

In the tests comparing differently produced wheat, conventional soil fertility management significantly reduced the amount of food eaten, there was also a significant interaction between crop protection and fertility management with significantly less consumption of the conventional food (Table 4).

As for the crop protection impact, the results of the first series of food preference tests in the winter of 2007–2008 differed from the results of the second series conducted in the summer of 2008. On the whole, significantly less of the conventional diet was eaten ($p < 0.01$), indicating at least an additional crop protection effect. Furthermore, the organic crop protection diet, CO, was preferred significantly to the conventional one, CC. On the other hand, the food preference test with the organic diet, OO, vs. the integrated diet with conventional crop protection, OC, showed a significantly higher preference for OC, indicating a positive effect of conventional crop protection, possibly due to the summer results. The organically protected and fertilized wheat grown in winter still showed a slightly better result, but the difference was

Table 2
Correlations between variables for rats given identical foods.

	Org food	Conv food	Total amont consumed	Consumed base food
Conv food	−0.213			
Total eaten	0.594***	0.335		
Consumed base	−0.383*	−0.155	−0.428*	
Weight increase	0.028	−0.121	−0.006	−0.176

Table 3
The effect of the management used for the test feeds on the amount of base food consumed g/d.

	Crop protection		
Fertilisation	Organic	Conventional	Mean
Organic	11.69	26.58	19.13
Conventional	19.99	31.38	25.68
Mean	15.84b	28.98a	

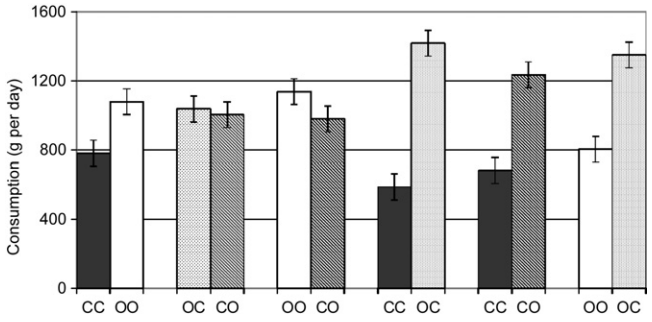

Fig. 1. Overall summary of the food preference tests with diets based on wheat produced in 2007. Total amounts eaten (g day^{-1}) by laboratory rats. Comparisons in pairs of wheat produced under conventional soil fertility management and conventional crop protection (CC), organic soil fertility management and organic crop protection (OO), organic soil fertility management and conventional crop protection (OC), and conventional soil fertility management and organic crop protection (CO). Bars show standard errors.

not statistically significant. The integrated diets, CO and OC, were preferred significantly to the conventional wheat, CC, but did not differ from each other (Fig. 1).

Regarding the amount of basic food eaten during the tests, the rats consumed significantly more ($p < 0.05$) if at least one of the test diets was grown with conventional plant protection. Comparing all test results rats ate significantly more of the base diet if they received at least one food with conventional crop protection but if the amount of the test food eaten is taken into account as a covariate then the only significant difference is an increase for those eating the conventional variant (Table 5).

The diet OC, organic soil fertility management plus conventional crop protection, was the most preferred food in the overall comparison (Fig. 1). This combination also displayed the lowest risk for lodging and mildew, a concurrence that is commonly ascribed to fertilizing. On the one hand, a high nitrogen availability enhances lodging and mildew. On the other hand, rats generally prefer organically fertilized wheat, which contains less nitrogen and protein [7,8].

4. Discussion

The results obtained from the food preference tests with wheat grown in 2005 and 2007 are not identical in all respects. The common feature is the positive influence of organic fertilization on food choice. In all cases the all organic (OO) wheat

Table 5
The amount of base food consumed by rats (g/d) receiving differently grown test foods.

	Crop protection		
Fertilisation	Organic	Conventional	Mean
Organic	15.40	20.00	17.70
Conventional	16.35	21.77	19.06
Mean	15.88	20.88	

(produced with organic fertilizer and organic crop protection) was preferred to the all conventional wheat (CC) as well as to the integrated diet with inorganic fertilizer. The role of plant protection is not clear, since the results of the two test years were contradictory. It could be that the health status of the plants is a more important food choice determinant than pesticide residues. In both harvests, differences in plant health occurred [6], which possibly influenced the consumption pattern of the rats. In all tests it was noted that significantly more of the basic food was consumed if diets grown with conventional plant protection were involved. The animals' metabolic needs might have changed. Investigations of crop protection agents (organophosphates) have shown metabolic effects in neonatal rats that can have a potential impact on obesity and diabetes [9]. Such possible interactions should be further investigated in topically specified tests.

According to Sclafani [4], only compositional differences reaching a critical level will prompt the test animal to choose for its own benefit. Such findings have been corroborated in previous wheat preference tests with laboratory rats [7,8]. The range of natural fluctuations would not compromise the nutritional adequacy of the two test wheat samples and therefore recurring significant preferences have to be triggered by other food characteristics that are not yet scientifically evaluated.

Furthermore, it has to be kept in mind that the test rats did not suffer from any deficiencies, which could have changed their feeding pattern accordingly.

5. Conclusions

Food preference tests with laboratory rats are suited for differentiation between diets based on wheat grown under different agricultural practices such as organic and inorganic soil fertility and crop protection management systems. A positive effect of organic fertilization was shown at a statistically significant level. An influence of different crop protection regimes on the amount of food intake in general was noticed, but could not be clarified with the experimental design used. In the complex instinctive select–reject decision process of food choice based on post-ingestive consequences, nutritional advantages might be more important than slight discomfort due to mycotoxins and/or pesticide residues. The plant's health status might provide additional positive clues for a sustainable choice. So far, the most reliable and consistent results have been obtained with tests comparing wheat from organic vs. conventional farming systems indicating the advantages of systems research. The reproducible highly significant preferences of all organic vs. all conventional diets based on wheat grown in 2005

Table 4
The effect of food management on the amount eaten g/d. Data from the tests of the 1st and 2nd series.

	1st series			2nd series		
	Crop protection					
Fertilisation	Organic	Conventional	Mean	Organic	Conventional	Mean
Organic	54.89a	63.99a	59.44A	45.61bc	63.01a	54.31A
Conventional	49.65ab	32.35b	41.00B	56.24ab	35.77c	45.99B
Mean	52.27	48.17		50.91	49.39	

and 2007 appear to corroborate the results obtained in this factorial field trial.

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