

# Consumer preferences for micronutrient strategies in China. A comparison between folic acid supplementation and folate biofortification

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## Abstract

*Objective:* Despite public health efforts, folate deficiency is still largely prevalent in poor, rural populations and continues to cause a large burden of disease. The present paper determines and compares consumer preferences for two folate strategies: folic acid supplementation *v.* folate biofortification, i.e. the enhancement of the folate content in staple crops.

*Design:* Experimental auctions with non-repeated information rounds are applied to rice in order to obtain willingness-to-pay for folate products. Thereby, GM or non-GM folate-biofortified rice (FBR) is auctioned together with rice that is supplemented with free folic acid pills (FAR).

*Setting:* Shanxi Province (China) as a high-risk region of folate deficiency.

*Subjects:* One hundred and twenty-six women of childbearing age, divided into a school ( $n$  60) and market sample ( $n$  66).

*Results:* Despite differences according to the targeted sample, a general preference for folate biofortification is observed, regardless of the applied breeding technology. Premiums vary between 33.9% (GM FBR), 36.5% (non-GM FBR) and 19.0% (FAR). Zero bidding behaviour as well as the product choice question, respectively, support and validate these findings. The targeted sample, the timing of the auction, the intention to consume GM food and the responsibility for rice purchases are considered key determinants of product choice. A novel ex-post negative valuation procedure shows low consistency in zero bidding.

*Conclusions:* While the low attractiveness of FAR provides an additional argument for the limited effectiveness of past folic acid supplementation programmes, the positive reactions towards GM FBR further support its potential as a possible complementary micronutrient intervention.

**Keywords**  
Consumer preferences  
Folic acid supplementation  
Folate biofortification  
Auctions  
China

Controlling micronutrient malnutrition is a major public health priority in China. Since the 1990s, China has experienced dramatic declines in the share of undernourished people and is, compared with other Asian countries, likely to achieve the UN 2015 target on nutrition<sup>(1,2)</sup>. Nevertheless, because the most important staple foods such as wheat and rice are poor folate sources, folate deficiency remains a serious health problem for children and women of childbearing age in rural areas of China. It is estimated that about 258 million Chinese people suffer from folate deficiency<sup>(3)</sup>. As a consequence, each year approximately 18 000 babies are born with a neural tube defect (NTD; e.g. spina bifida), i.e. about 9% of the global prevalence. With respect to Shanxi Province, one of China's poorest rural regions, the situation is even more problematic. Each day about 6.5 births are

affected by an NTD, leading to the world's highest rate of birth defects<sup>(4)</sup>.

Like any other micronutrient deficiency, current policy interventions to reduce folate deficiency are built mainly upon pharmaceutical supplementation and/or industrial fortification. Although China is primarily targeted at folic acid supplementation<sup>(5,6)</sup>, past supplementation programmes are known to have a short-term effect<sup>(7)</sup>, by which the use of folic acid pills is currently low<sup>(8)</sup>. In Shanxi Province, for example, only 7.7% of women of childbearing age ever used folic acid pills<sup>(9)</sup>, while 44% of pregnant women do not achieve the recommended daily dose of folate<sup>(10)</sup>. As most of them are not aware of the need to take folic acid supplements<sup>(11)</sup>, the limited success of such programmes is also due to the large number of unintended pregnancies<sup>(12)</sup>. Therefore, it will be difficult

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and costly to reach all women of childbearing age, especially when continuation of the programme is crucial to keep them motivated<sup>(13)</sup>. On the other hand, folic acid fortification of China's two most important staple crops is expected to pose practical, technical and financial difficulties, partly due to the highly segmented rice and wheat milling sectors<sup>(14,15)</sup>.

To address folate deficiency when folic acid-based strategies are less feasible or effective, genetic engineering has been recently applied to develop staple crops with a higher folate content<sup>(16)</sup>. In 2007, for instance, folate-biofortified rice (FBR) was developed through metabolic engineering<sup>(17)</sup>. This GM crop is currently the most advanced case of folate biofortification<sup>(18)</sup> and is expected to be a highly cost-effective means to reduce the health burden of folate deficiency in China<sup>(19)</sup> and its regions<sup>(3,20)</sup>. China, a key GM crop producer<sup>(21)</sup>, recently granted a biosafety certificate for pest-resistant GM rice<sup>(22)</sup>, which further supports its potential. Although it is possible to use conventional breeding techniques to elevate folate levels in rice<sup>(16)</sup>, similar to other biofortification efforts in maize, wheat, beans, cassava and rice<sup>(23)</sup>, such a crop is not yet developed.

From a marketing point of view, knowing the needs and potential reactions of the targeted populations contributes to a successful implementation of health interventions, especially in the case of controversial products such as GM foods. As Musgrove and Fox-Rushby<sup>(24)</sup> stated: 'The effectiveness of an intervention and, therefore, the degree to which it deserves priority depend on how far it is culturally appropriate or acceptable for the population it is intended to benefit' (p. 227). Although previous consumer studies showed that Chinese people are generally favourable of GM food<sup>(25–28)</sup>, especially if health benefits are attached<sup>(29–32)</sup>, it remains to be proved if they would be as enthusiastic for GM biofortified crops when non-GM alternatives are available. In other words, to assess the true potential of GM biofortification it is crucial to analyse consumer preferences for different micronutrient interventions simultaneously.

The present paper aims to investigate and compare consumers' willingness-to-pay (WTP) and preference for folic acid supplements (non-GM) *v.* folate biofortification (GM and non-GM). Gaining insight in preferences for different folate strategies allows one to benchmark their potential market demand, predict the impact of information about the applied technology, develop activities to adequately reach the target population and, thus, increase its success rate in areas where the need is the highest. Therefore, an economic valuation study is conducted in Shanxi Province, a poor, developing region that accounts for the largest burden of folate deficiency in China<sup>(3)</sup>. Due to the large body of evidence on the effect of maternal folate deficiency on the risk of having a baby with an NTD<sup>(33,34)</sup>, as well as the high burden of maternal folate deficiency<sup>(3)</sup>, only women of childbearing age are targeted in the present study.

## Methodology

In order to analyse WTP for folate strategies in China, non-hypothetical experimental auctions are organized with China's main staple crop, i.e. rice, as the food vehicle for folate enhancement. Therefore, two rice products are simultaneously auctioned: rice enriched with folate (FBR) and rice supplemented with seven folic acid supplements (FAR). As such, each auctioned product contains the same amount of rice (1 kg) and folate (about forty times more than in regular rice), by which one could achieve the recommended folate intake level through the consumption of either FBR or FAR. In this way, China's most common way to improve folate intake levels as well as a potential alternative strategy are brought into the rice auction. Hence, we address the need to include substitutes in GM food auctions<sup>(35–37)</sup>. Such a multiple-product auction design is often applied to simultaneously determine consumers' WTP for different food products<sup>(38–41)</sup>, including rice<sup>(42,43)</sup>, GM foods<sup>(44–46)</sup> and biofortified crops<sup>(47)</sup>.

While FAR is currently not sold at the marketplace, FBR is still in a development phase. Therefore, the present study is considered an *ex-ante* evaluation of the potential of folate strategies. FAR, for example, might be valuable as it aims to promote folic acid supplements through the food supply chain.

Previous studies on consumer preferences for conventional biofortified foods were mainly targeted at provitamin A-enriched crops, like sweet potato in Uganda<sup>(48)</sup>, maize in Kenya<sup>(47)</sup>, Mozambique<sup>(49)</sup> or Zambia<sup>(50)</sup>, and cassava in Brazil<sup>(51)</sup>. With respect to GM biofortified foods, valuation studies focused on provitamin A-enriched 'Golden Rice' in the Philippines<sup>(36,52)</sup> and the USA<sup>(53)</sup>, but also on rice with enhanced vitamin levels in China<sup>(30)</sup> or vitamin E/antioxidant cookies in Italy<sup>(54)</sup>.

Besides GM foods with farmer benefits<sup>(55)</sup>, such as insect-resistant rice in China<sup>(28)</sup>, experimental auctions are more and more applied to analyse WTP for GM crops with consumer/health benefits<sup>(45,56,57)</sup>, and GM biofortified crops (Golden Rice) in particular<sup>(36,52)</sup>. Besides provitamin A, rice auctions have also examined other quality attributes like quality labels in Senegal<sup>(42)</sup> and parboiling technologies in Benin<sup>(43)</sup>.

The auctions are targeted towards female rice consumers of childbearing age from Shanxi Province, i.e. key beneficiaries of folate interventions. Based on the research location, two target groups are distinguished: a school and a market sample. Although the former is a specific target group, which represents a future generation of pregnant women, the latter is considered to be more representative of the general target population. The total sample encompasses 126 female rice consumers from Taigu, Shanxi Province, of whom sixty students participated at school and sixty-six non-students were recruited near the market place. The auction size varied between fifteen and twenty persons. Given that experimental

**Table 1** Information sheets per auction round and auctioned product

Folate-enriched rice (FBR)	Rice supplemented with folic acid pills (FAR)
<p>Auction round 1: Folate content†</p> <ul style="list-style-type: none"> <li>● 1 kg rice with high folate content</li> <li>● Same taste, appearance, ... as regular rice‡</li> <li>● 40 times more folate than your bag</li> <li>● By eating this rice each day, you eat enough folate intake level per day</li> </ul> <p>Auction round 2: Folate benefits§</p> <p>Health benefits of folate consumption:</p> <p>Pregnant women</p> <ul style="list-style-type: none"> <li>● drastically reduces the risk of having a baby with a birth defect</li> <li>● reduces the risk of having a still birth</li> </ul> <p>All people</p> <ul style="list-style-type: none"> <li>● reduces the risk of different types of cancers and heart and cardiovascular diseases</li> <li>● reduces the risk of Alzheimer</li> <li>● reduces the risk of anaemia (lack of oxygen in the blood)</li> <li>● improves the overall resistance to diseases</li> </ul> <p>Auction round 3: GM technology  </p> <ul style="list-style-type: none"> <li>● This product is made using genetic modification (GM)</li> </ul>	<ul style="list-style-type: none"> <li>● 1 kg regular rice sold together with seven folate pills</li> <li>● 40 times more folate than your bag</li> <li>● By taking one pill each day, you achieve the recommended folate intake level per day</li> </ul> <p>Health benefits of folate consumption:</p> <p>Pregnant women</p> <ul style="list-style-type: none"> <li>● drastically reduces the risk of having a baby with a birth defect</li> <li>● reduces the risk of having a still birth</li> </ul> <p>All people</p> <ul style="list-style-type: none"> <li>● reduces the risk of different types of cancers and heart and cardiovascular diseases</li> <li>● reduces the risk of Alzheimer</li> <li>● reduces the risk of anaemia (lack of oxygen in the blood)</li> <li>● improves the overall resistance to diseases</li> </ul> <ul style="list-style-type: none"> <li>● This product is not made using genetic modification (GM)</li> </ul>

FBR, folate-biofortified rice; FAR, rice supplemented with folic acid pills.

Note: The information sheets are translated from Chinese. A 1 kg (2 Jīn) bag of regular rice costs 5.2 Yuan (¥). 1 ¥ is approximately \$US 0.15.

†A regular rice bag of 1 kg contains about 80 µg folate<sup>(69)</sup>, while an FBR bag the same size contains approximately 3000 µg<sup>(3,17)</sup>. To be able to compare FBR with FAR, we attached seven folic acid pills to the bag (400 µg/pill). Based on the current daily rice and folate consumption patterns of women in Shanxi Province, respectively estimated at 133 g rice<sup>(90)</sup> and 190 µg folate<sup>(6)</sup>, Shanxi women could achieve the recommended folate intake level for a day either by consuming a regular portion of folate-enriched rice or by taking a folic acid pill.

‡Bekaert *et al.*<sup>(18)</sup>.

§Molloy and Scott<sup>(91)</sup>, Bailey *et al.*<sup>(92)</sup>, Geisel<sup>(93)</sup> and Blancquaert *et al.*<sup>(16)</sup>.

||A general GM food definition is mentioned, derived from key reports.

auctions are primarily conducted with students, the study allowed the comparison of valuations between student and non-student samples<sup>(58)</sup>.

For a comprehensive overview of the auction design, from recruitment to debriefing, see the Supplementary Materials.

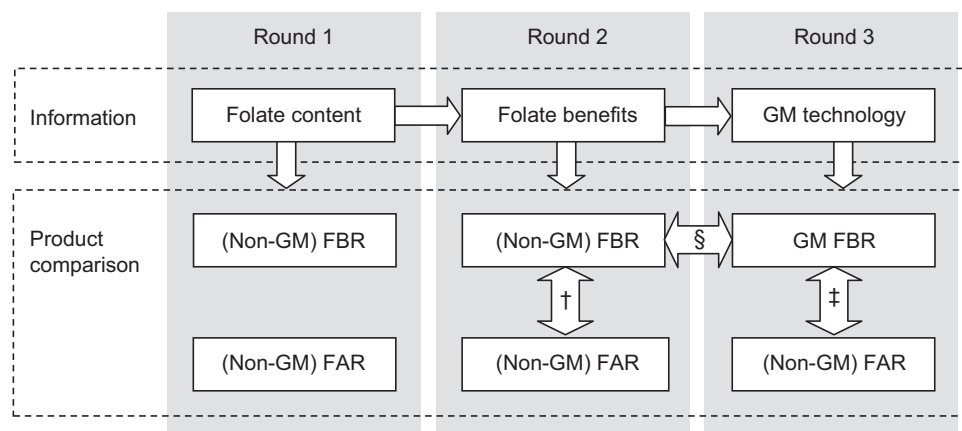
### **Auction design**

The design applied follows the general approach of food auctions: briefing (including collection of informed consent), training, practice, bidding rounds and debriefing. The bidding procedure is based on a second price (Vickrey) auction mechanism<sup>(59–61)</sup>, by which the highest bidder of the binding round is selected as the buyer and, thus, has to purchase the selected product at the amount of the second highest bidder. Thereby, an endowment procedure is employed, which requires people to bid the amount they are prepared to pay to exchange an initial given product, i.e. 1 kg of regular rice (costing 5.2 Yuan (¥); 1 ¥ is approximately \$US 0.15), with FBR or FAR. To control for product order effects and to reduce expectation errors, the auctioned products are randomly coded and the order is randomized.

A within-subject design with non-repeated information rounds is used. Several authors lend support for such a design<sup>(38,62)</sup>, if extensive training<sup>(63)</sup> and a single binding approach are incorporated<sup>(41,64)</sup>. In three subsequent bidding rounds, information about (i) the folate content, (ii) the folate benefits and (iii) the applied technology is provided (Table 1). Except for the last bidding round, the

message is similar for the two products. The participants received price information about the endowed product, but not about FBR or FAR. With respect to the latter, the present study did not measure and control for the impact of consumers' knowledge of the current cost of folic acid supplements (i.e. about 10 ¥/month), which is considered an important limitation of the study.

Because GM information is provided latest, three product comparisons can be examined (Fig. 1). First, WTP values for FBR and FAR in the second round, i.e. when the participants are aware of their folate content and potential health benefits, refer to non-GM strategies to increase folate consumption (non-GM comparison). To reduce the risk that participants assume that FBR in this auction round is caused by GM technology, specific terms that might be associated with this technology are not mentioned during the recruitment phase and the first two auction rounds, as well as in the auction materials (see Supplementary Materials). In the third round, the focus shifts towards the GM nature of FBR and the comparison with (non-GM) FAR (GM comparison). In other words, it measures the effect of awareness of the GM technology in FBR on both folate products. Third, the difference between WTP for FBR before and after the third round reveals the impact of the applied breeding technology, i.e. whether FBR is based on conventional or GM breeding techniques (FBR comparison). Whereas the latter comparison is the result of juxtaposing FBR bids from subsequent information rounds, the former two comparisons represent bid differences between both



**Fig. 1** Comparison of WTP values for FBR (non-GM, GM) and FAR (non-GM) based on the three information rounds (†non-GM comparison; ‡GM comparison; §FBR comparison). Note that as participants do not receive information regarding the applied technology in the first and second rounds, their FBR bids reflect WTP values for the non-GM product. Due to the high correlation between bids of the first and second rounds, only the latter values are used in the analysis, as they are based on additional information about the benefits (WTP, willingness-to-pay; FBR, folate-biofortified rice; FAR, rice supplemented with folic acid pills)

folate products in the same round. Although our fixed information order allows for product comparisons for each participant, order effects might be at stake, which is an important limitation of the auction design.

At the end of the bidding rounds, the participants stated their preference when both folate products would be available in the market. A similar approach is also used in contingent valuation methods with other biofortified products<sup>(36)</sup>. Our question reflects an ‘informed’ choice and consists of three categories (FBR, FAR, indifference). Thus, the focus is on the difference between supplementation and GM biofortification, by which the former is characterized by a higher degree of compliance.

Given the controversy associated with the use of GM technology in foods, the most reluctant bidding behaviour is expected to occur in the last information round. Therefore, zero bidders in this round receive an additional bidding slip to determine whether they would be interested to buy the auctioned good at a value below the price of regular rice. Stated differently, these zero bidders had the opportunity to bid a negative WTP.

This approach is relatively new in food auction literature<sup>(64–66)</sup> and is particularly relevant when using controversial goods<sup>(65)</sup>, like GM food. Contrary to the approach of Parkhurst *et al.*<sup>(65)</sup>, negative valuations are introduced as an ex-post bidding procedure. Even though such negative values are strictly speaking hypothetical, they help to gain insight in the motives behind zero bidding behaviour. In this way, we partially address the need for follow-up questions in valuation research<sup>(67)</sup>.

**Data analysis**

Statistical analysis consists mainly of Wilcoxon signed-rank tests and multinomial logistic regression. Because the WTP values are not normally distributed, but left-skewed,

the non-parametric Wilcoxon signed-rank test is appropriate to test differences between subsequent information rounds (e.g. FBR comparison), as well as between simultaneously auctioned goods (e.g. non-GM and GM comparison), in line with Roosen *et al.*<sup>(41)</sup>. This test is similar to the sign test, but is assumed to be more powerful<sup>(41)</sup>. Multinomial logistic regression is employed to explore the determinants of product choice.

**Results**

**Sample characteristics**

Table 2 describes the total sample and compares significant differences between the two sub-samples. The sociodemographic profile of the sample is closely related to the setting of the experiment, i.e. a poor, rural, farmer region. Only one woman was known to be pregnant during the experiment.

Regardless of the correctness of the intake, 17.5% of the sample ever took folic acid, exceeding previous findings in Shanxi Province<sup>(9–11,68,69)</sup>, which varied between 7.7% and 15.3%. The limited use, as well as the high familiarity with NTD cases, underlines the need to address folate deficiency, in line with folate status<sup>(10)</sup> and NTD prevalence studies<sup>(70)</sup>.

Despite the high subjective knowledge of GM food (64.3%), the objective knowledge score is relatively lower (50.1%). Other Chinese studies also pointed out the lack of GM knowledge<sup>(25–27)</sup> and the discrepancy between subjective and objective knowledge<sup>(30)</sup>. About 81.7% of the total sample would not refuse to consume GM food, which further supports the optimistic view of Chinese consumers towards GM food<sup>(25–31)</sup>.

Regarding product choice, the results show that 66.7% is favourable of FBR, while only 15.1% prefers FAR and

**Table 2** Variable descriptions of the experiment sample

Timing†	Variable	Description	School sample		Market sample		Total sample		Sub-sample differences	
			Mean	SD	Mean	SD	Mean	SD	$\chi^2$ test‡	df
Auction design characteristics										
	TARGET	Targeted sample (0 = school sample; 1 = market sample)	–		–		0.52	0.50	–	
	TIMING	Timing of the auction (0 = morning; 1 = afternoon)	0.67	0.48	0.76	0.43	0.71	0.45	1.27	1
Sociodemographic variables										
At start	AGE	Age of the participant (years)	21.10	1.41	40.42	10.18	31.07	12.17	212.39***‡	125
	EDUC	Education (0 = low; 1 = high)¶	1.00	0.00	0.26	0.44	0.61	0.49	72.89***	1
	RICEPURCH	Responsible for the rice purchases in the household (0 = no; 1 = yes)	0.05	2.20	0.94	0.24	0.52	0.50	99.54***	1
	FARMER	Involved in farming activities (0 = not a farmer; 1 = farmer)	0.62	0.49	0.62	0.49	0.62	0.49	0.003	1
	FUTPREG	Intention to become pregnant in the future (0 = no; 1 = yes)	0.97	0.18	0.09	0.29	0.51	0.50	96.44***	1
	RESIDENCE	Residence (0 = urban; 1 = rural)	0.73	0.45	0.89	0.31	0.82	0.39	5.43*	1
Variables related to folate/folic acid										
Before round 2	FOLICUSE	Ever used folic acid supplements (0 = no; 1 = yes)	0.12	0.32	0.27	0.45	0.20	0.40	4.81*	1
	NTDKNOW	Knowledge of a women who delivered a baby with an NTD (0 = no; 1 = yes)	0.38	0.49	0.45	0.50	0.42	0.49	0.65	1
Variables related to GM food										
Before round 3	SUBJKNOW	Subjective/perceived knowledge of GM food (0 = no; 1 = yes)	0.97	0.18	0.35	0.48	0.64	0.48	53.31***	1
	OBJKNOW§	Objective knowledge of GM food (% of correct statements)	0.67	0.17	0.32	0.24	0.49	0.27	87.18***‡	125
	INTENTION	If GM food would be available for consumption, I would eat it (1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree)	3.12	0.69	3.20	0.97	3.16	0.84	7.71	4
Variable related to the auctioned products										
After round 3	CHOICE	If you could buy the two auctioned products in the supermarket, which one would you buy? (0 = FBR, 1 = FAR; 2 = indifference)	0.68	0.83	0.36	0.72	0.52	0.79	7.25*	2

FBR, folate-biofortified rice; FAR, rice supplemented with folic acid pills; NTD, neural tube defect.

\* $P < 0.05$ , \*\*\* $P < 0.001$ .

†The first column refers to the timing of the self-administered survey question. The auction design characteristics (TARGET and TIMING) are not included in the survey.

‡Due to the metric scale of the variables AGE and OBJKNOW, the figures refer to  $F$  values, based on one-way ANOVA.

§Objective knowledge is measured through six true-or-false statements, in line with previous research<sup>(94,95)</sup>.

¶A low and high education level refers to, respectively, primary/secondary school and college or above.

18.3% is indifferent. In nearly all cases, the product with the highest value is preferred, which demonstrates that the bids represent the economic value a consumer attaches to the folate products, rather than their evaluation of the (preferred) costs.

When looking at the sub-samples, the school sample represents a pool of women of childbearing age that is remarkably younger, nearly responsible for rice purchases and has less rural consumers. Given their age, most of them intend to become pregnant, which explains the limited use of folic acid supplements. While these students know more about GM food, they prefer FBR less than in the market sample, but still more than FAR.

**Comparison of folate strategies**

Table 3 gives an overview of the average bids and the share of zero bidders for each pair of auctioned folate products. Thereby, the results are split up according to the targeted sample. Somewhat surprising, the Wilcoxon test reveals that WTP values for FBR are significantly higher than for FAR, even when the former is associated with GM technology. In general, mean WTP values for FBR vary between 1.76¥ (GM) and 1.90¥ (non-GM), compared with 0.99¥ for FAR. In other words, the participants are prepared to pay a premium of 33.9%, 36.5% and 19.0% for, respectively, GM and non-GM folate biofortification and folic acid supplementation. The results confirm the expectation that GM crops with consumer benefits are positively embraced by consumers, especially in developing countries, such as India<sup>(71)</sup>, the Philippines<sup>(52)</sup>, Brazil<sup>(51)</sup> and China<sup>(30)</sup>. Overall, awareness of the applied GM technology generally does not significantly affect consumers' valuation. However, in the group of students, the GM nature of FBR is negatively valued. While previous GM food auction studies<sup>(58,72)</sup> showed that bids of non-student and student subjects do not differ significantly, the present findings suggest the opposite.

With respect to zero bids, a similar pattern is observed: large differences in the non-GM comparison, regardless of the targeted sample, and sample differences in the other product comparisons. In the school sample, for example, zero bidding for GM FBR is substantially more present than in the market sample.

**Determinants of product choice**

Multinomial logistic regression analysis is conducted to examine potential determinants of product choice. The variable TARGET is incorporated to take into account the differences between the two sub-samples. As shown in Table 4, the model explains 33.6% of the variance. The targeted sample, the timing of the auction, intention to eat GM food and being responsible for the rice purchases are considered as key factors.

The effect of these variables can be interpreted by the parameter estimates of the multinomial logistic regression.

**Table 3** Comparison of WTP values between non-GM/GM FBR and non-FAR, mean bids (¥), share of zero bids and bid differences (Δ), per targeted sample and product comparison

	Non-GM comparison			GM comparison			FBR comparison		
	FBR (non-GM)		Wilcoxon Test	FBR (GM)		Wilcoxon Test	FBR (non-GM)		Wilcoxon Test
	Mean	sd		Mean	sd		Mean	sd	
School sample (n 60)	1.62	1.17	0.82	1.35	1.32	0.42	1.62	1.17	0.27
Mean bid (¥)									
Zero bids (%)	3.3		-27.6	18.3		-6.7	3.3		-15.0
Market sample (n 66)	2.16	1.96	0.99	2.14	1.87	1.20	2.16	1.96	0.02
Mean bid (¥)									
Zero bids (%)	6.1		-22.7	12.1		-28.8	6.1		-6.0
Total (n 126)	1.90	1.65	0.91	1.76	1.67	0.82	1.90	1.65	0.14
Mean bid (¥)									
Zero bids (%)	4.8		-24.6	15.1		-18.2	4.8		-10.3

WTP, willingness-to-pay; FBR, folate-biofortified rice; FAR, rice supplemented with folic acid pills.  
 Note: ¥ 1 ~ \$US 0.15.  
 \*\*\*P < 0.001.

**Table 4** Significant determinants of the consumers' preference for folate products, by multinomial logistic regression, likelihood ratio tests and parameter estimates per binary logistic comparison

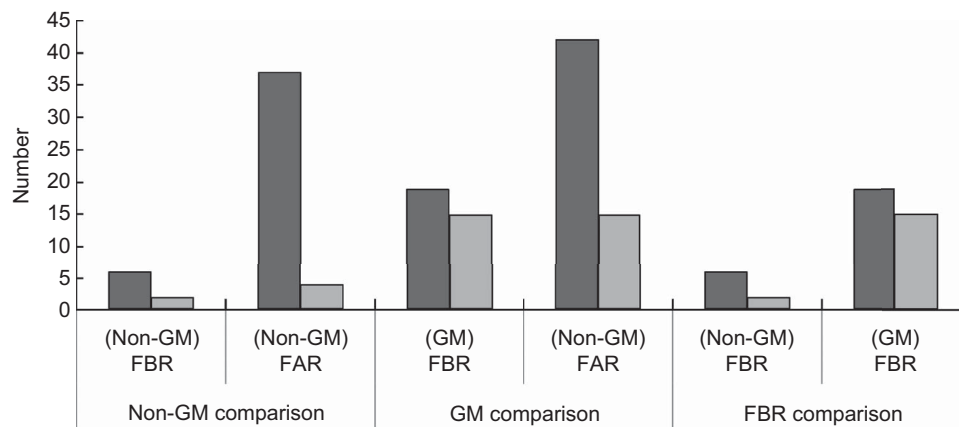
Preference variable (dummy†)	Likelihood ratio tests		GM FBR v. FAR‡		GM FBR v. indifference‡		FAR v. indifference‡	
	$\chi^2$	<i>P</i>	B	<i>P</i>	B	<i>P</i>	B	<i>P</i>
RICEPURCH (no)	<b>7.38</b>	0.02			2.39	0.10	4.86	0.01
FARMER	1.80	0.41						
RESIDENCE	0.21	0.90						
FOLICUSE	1.64	0.44						
NTDKNOW (no)	4.01	0.13					-1.43	0.05
SUBJKNOW	1.81	0.40						
OBJKNOW	1.93	0.38						
INTENTION	<b>7.47</b>	0.02	0.69	0.01				
TARGET (market)	<b>7.17</b>	0.03	3.63	0.05			-5.49	0.01
TIMING (morning)	<b>7.38</b>	0.03			-2.43	0.01		
Model	<b>40.52</b>							
Nagelkerke $R^2$	<b>0.34</b>							

FBR, folate-biofortified rice; FAR, rice supplemented with folic acid pills.

Note: The dependent variable, consumer preference, consists of three categories: FBR preference, FAR preference and indifference. To compare all groups of the dependent variable, three binary logistic regressions are presented. Bold indicates a significant effect.

†The parameter estimates of the dummy variables refer to a specific category, expressed in parentheses.

‡Reference category.



**Fig. 2** Number of all zero bidders (■) and new zero bidders (▨) regarding FBR and FAR, per product comparison. Note that a 'new zero bidder' in round  $x$  is defined as a participant who does not bid zero in round  $x - 1$ , but starts to bid zero in round  $x$  (FBR, folate-biofortified rice; FAR, rice supplemented with folic acid pills)

First, a targeted sample effect is observed. In comparison with the students (school sample), the majority of the market sample prefers folate-enriched GM rice over the non-GM alternative. They are also more intended to take an indifferent position rather than to choose FAR. Although students' preference is more oriented towards FAR, it is important to note that this does not mean that students reject FBR. They only prefer supplementation more than consumers from the market sample, regardless of the size of their bids. Second, indifference is more likely to occur in the morning sessions, while participation in the afternoon increases the likelihood to choose FBR. While several auction studies with staple crops reported higher WTP values in the morning<sup>(42,43,73,74)</sup>, which is likely due to hunger and increased interest in buying and consuming food, the present study reports a somewhat similar time-of-the-day effect that refers to product choice. Respondents in the morning are more favourable to all folate products,

rather than preferring one. Third, consumers in charge of the rice purchases in the household have a lower probability to be indifferent. Finally, as expected, the odds to belong in the group of consumers that favours FBR are positively influenced by an intention to consume GM food. A similar positive effect is found in other GM food studies<sup>(26,75-77)</sup>. Although intention is assumed to predict GM food behaviour more accurately than attitude<sup>(76,78)</sup>, in line with behaviour theory<sup>(79)</sup>, the relationship is often not straightforward<sup>(80)</sup>, as demonstrated for GM food valuation studies<sup>(75)</sup>. Despite its insignificance, NTDKNOW also seem to drive consumers towards FBR.

#### **Zero bidding behaviour and negative valuations**

Figure 2 juxtaposes the total number of zero bidders (see Table 2) and 'new zero bidders'. The latter is defined as participants who start to bid zero after they received new information. The total number of zero bidders is the sum

of new zero bidders and those who did not change their zero bid of the previous bidding round. Therefore, in the first round the number of new zero bidders equals the total number of zero bids. Zero bids in the non-GM product comparison (second round) most likely refer to consumers' reluctance of the information about the folate content (first round) and the folate benefits (second round). Reasons for zero bidding in this comparison round might be related to concerns regarding the high folate content or the inconvenience of taking pills (daily). As expected, most participants turn their positive FBR bid into a zero bid upon learning that GM technology is used (GM comparison). Surprisingly, the number of FAR zero bids also increases after this information treatment. Together with the large discrepancy between new zero bidders in the 'FBR comparison', one can conclude that non-GM FBR provokes the least negative reactions, but the evaluation of GM FBR is not as negative as one would have thought. Stated differently, the absence of a reduction in zero bidding behaviour towards non-GM FAR further underlines the general preference for FBR.

The additional negative valuation approach somewhat nuances the aforementioned figures regarding the 'GM comparison'. Out of the forty-four FBR zero bidders in the third round, only 15.8% are consistent in their reluctance and are not willing to buy FBR, even if there would be a discount. The other participants claim to accept FBR if it would be cheaper, i.e. between 0.2¥ and 2.0¥. These figures are comparable with another Chinese GM rice study<sup>(30)</sup>. In the case of the non-GM FAR, only 7.3% of forty-two zero bidders are not interested at any price. This demonstrates that a large part of FAR zero bidders considers the value of the additional free folic acid supplements not higher than regular rice, but will not be averse of buying FAR when the price would be more competitive, i.e. on average 0.57¥ lower. Comparison of both products shows that awareness of the GM technology causes more people to maintain their initial zero bids for FBR, but not as much as would have been expected.

## Discussion

The present paper analyses consumers' WTP for two folate strategies: biofortification, based on GM or conventional breeding techniques, and supplementation. The novelty of the application of non-hypothetical experimental auctions not only refers to the comparison of present and novel micronutrient strategies, but is also related to the targeted sample, i.e. women of childbearing age from a folate deficient region. Although the two subsamples represent important target groups of folate consumption, the results of the school sample should be carefully interpreted, especially when generalizing the conclusions of this ex-ante valuation study.

The results show a significantly higher WTP for folate biofortification compared with folic acid supplementation,

even if consumers are aware of the applied GM technology. The convenience of the high folate concentrations in FBR seems to outweigh the absence of a controversial technology and the compliance of taking pills in the case of FAR.

The study also sheds a novel light on zero bidding for controversial goods through the elicitation of negative values as an ex-post survey question. In the case of GM foods with health benefits, only a small part of the zero bidders consistently refused to buy GM FBR when having the option to submit a negative bid. Future research should further explore the potential of culturally applicable follow-up questions to determine the true motives behind zero bids<sup>(67)</sup>, like thought-listening questionnaires<sup>(35)</sup>.

Furthermore, measuring product choice at the end of the auctions can be considered an additional tool to validate the bids and to examine whether consumers actually understand the purpose of bidding. As Lusk *et al.*<sup>(81)</sup> stated, if a participant would have indicated a preference for the product with the lowest bid, she would probably have expected that her response could have influenced the future price of the auctioned good(s).

Together with the limited access to folic acid in rural areas<sup>(7)</sup>, the poor knowledge of the correct time of intake<sup>(10)</sup>, the low awareness of the need for folate<sup>(11)</sup> and the large number of unintended pregnancies in China<sup>(12)</sup>, the novel insights on the low attractiveness of FAR provide an additional argument for the limited success of past folic acid supplementation programmes and the current low use of folic acid pills. It is important to note that in order to elicit consumer preferences for these micronutrient interventions, rice is selected as the food vehicle of the folate enhancement. Therefore, future research should examine whether FAR is a feasible, cost-effective and sustainable option to increase folic acid intake.

Given the differences between the school and market samples, by which the unattractiveness of FAR is less pronounced in the school sample, one might advocate to target folic acid supplementation interventions towards the future generation of mothers. Nevertheless, the results demonstrate that folate biofortification could be a well-accepted alternative micronutrient strategy. Especially because those responsible for the rice purchases, mainly represented in the market sample, are better placed to choose one of the two folate products, the general FBR preference should be taken into account when evaluating the potential of micronutrient interventions in public health. In line, the intention to consume GM food, which is found to be a determinant of preference for FBR, further supports the positive reactions towards GM biofortification in China.

From a purely economic perspective, the WTP values could be used, and juxtaposed with the development and implementation costs of these micronutrient strategies, in order to decide whether it is beneficial and commercially viable to adopt them or to set a price level<sup>(82)</sup>, e.g. based on a premium that ensures a sufficient market share<sup>(83)</sup>



and attracts farmers to produce GM biofortified crops<sup>(84)</sup>. In the Philippines, for instance, a premium rice variety was used to deploy Golden Rice<sup>(85)</sup>. The downside of such a pricing strategy is its contradiction with the pro-poor, pro-rural, public health mission of micronutrient strategies<sup>(86)</sup>. Even though our study revealed that poor consumers are prepared to pay for FBR, the ability to pay might be an important constraint, as shown in valuation studies on health-care options in poor populations<sup>(87)</sup>. Therefore, the WTP figures should rather be interpreted as consumer preferences of FBR or FAR over regular rice. Such economic values can be used to inform and support public health and – in the case of FBR, agribusiness decision makers<sup>(82,88)</sup>. As such, strong preferences for FBR could contribute to priority setting in the field of (regional) folate interventions.

Nevertheless, if both FBR and FAR would be part of a national public health programme, it will be a research and policy challenge to simultaneously attract farmers, who seek to make profits out of the added value of FBR; poor consumers, who will have different rice varieties at their disposal and need to be convinced and informed to consume folate products (correctly); health programme planners and other stakeholders, who will need to be involved to commercialize, distribute and promote these interventions, while taking into account the cost implications.

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### Supplementary Materials

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