Supporting information for Food waste and its associated environmental impacts of workplace buffet-style canteens in Beijing, China

**Table. S1. Parameters of cooked food to agricultural products**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Item****(kg/kg)** | **Staple food** | **vegetable** | **meat** | **Sea****food** | **eggs** | **soy food** | **nuts** | **fruits** | **Data****sources** |
| P1 | 1.50 | 0.93 | 0.73 | 0.85 | 1 | 5 | 1 | 1 | [1-2]; Own estimation |
| P2 | 1.40 | 1.5 | 1.87 | 1.18 | 1.18 | 0.75 | 1 | 1 |  [3] |

**Note:** P1 is the conversion factor of cooked food to raw food. P2 is the conversion factor of the raw food equivalent to agricultural products.

**Table. S2. Parameters about ecological footprint of food waste in Beijing** [4]

|  |  |  |  |
| --- | --- | --- | --- |
| **Category** | **Average productivity of land used to produce *i* food Y*i* /(kg/hm2)** | **Land type** | **equivalence factor of *j* productive land R*j*** |
| Rice | 7133.91 | farmland | 1.32 |
| Wheat | 5957.41 | farmland | 1.49 |
| Other cereals | 6697.70 | farmland | 1.32 |
| Beans | 1600.19 | farmland | 0.83 |
| Vegetables | 58756.01 | farmland | 1.38 |
| Pork | 2992.82 | farmland | 1.59 |
| Beef | 11613.66 | farmland | 1.59 |
| 39.14 | grassland | 0.71 |
| Mutton | 16017.37 | farmland | 1.59 |
| 33.58 | grassland | 0.71 |
| Poultry | 3869.26 | farmland | 1.59 |
| Other meats | 3431.04 | farmland | 1.59 |
| Seafood | 9651.33 | Water | 0.48 |
| Eggs | 3531.92 | farmland | 1.59 |
| Nuts | 1044.91 | Forest | 2.36 |
| Fruits | 16757.19 | Forest | 0.74 |

Notes: In our research, we aggregated the 14 categories of food into 8 categories: staple food, vegetables, meats, sea food, eggs, soy food, nuts and fruits. The Y*i* and R*j* of staple food is the average of rice, wheat and other cereals; The Y*i* and R*j* of meats is the average of pork, beef, mutton, poultry and other meats.

**Table. S3. Water footprint of food waste per unit in Beijing (m3/kg)** [5]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Cereals** | **Beans** | **Vegetables** | **Pork/ Beef/ Mutton** | **Poultry** |
| 1.19 | 2.20 | 0.19 | 14.37 | 3.50 |
| **Egg** | **Seafood** | **Fruits** | **Tea-leaves** |  |
| 2.90 | 5.00 | 0.51 | 1.81 |  |

Notes: In our research, we aggregated the 9 categories of food into 8 categories: staple food, vegetables, meats, sea food, eggs, soy food, nuts and fruits. The carbon footprint of staple food is the cereals; the carbon footprint of meats is the average of pork/beef/mutton and poultry; the carbon footprint of nuts is the carbon footprint of tea-leaves.

**Table. S4. Carbon footprint of food waste per unit in Beijing (kgCO2eq/kg)** [6]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Rice** | **Wheat** | **Other Cereals** | **Beans** | **Vegetables** | **Pork** |
| 3.56/3.98 | 2.87/3.30 | 2.88/3.30 | 3.22/3.64 | 2.65/3.04 | 7.30/7.70 |
| **Beef** | **Mutton** | **Poultry** | **Other meat** | **Seafood** | **Egg** |
| 26.22/26.62 | 32.12/32.52 | 6.55/6.95 | 25.62/26.03 | 3.45/3.83 | 4.97/5.38 |

Notes: In our research, we aggregated the 12 categories of food into 8 categories: staple food, vegetables, meats, sea food, eggs, soy food, nuts and fruits. The carbon footprint of staple food is the average of rice, wheat and other cereals; the carbon footprint of meats is the average of pork, beef, mutton, poultry and other meat; the carbon footprint of nuts and fruits is the carbon footprint of all plant food.

**Table. S5. The nitrogen contents of different food ((N*i*，kg/kg)** [7]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Rice** | **Wheat** | **Other Cereals** | **Beans** | **Vegetables** | **Nuts** | **Fruit** |
| 0.0124 | 0.0215 | 0.0188 | 0.0586 | 0.0043 | 0.027 | 0.0017 |
| **Pork** | **Beef** | **Mutton** | **Poultry** | **Other Meat** | **Seafood** | **Egg** |
| 0.0240 | 0.0250 | 0.0230 | 0.0240 | 0.0240 | 0.0218 | 0.0168 |

Notes: In our research, we aggregated the 12 categories of food into 8 categories: staple food, vegetables, meats, sea food, eggs, soy food, nuts and fruits. The nitrogen content of staple food is the average of rice, wheat and other cereals; The nitrogen contents of meats is the average of pork, beef, mutton, poultry and other meat.

**Table. S6. The N budget and use efficiencies for different processes of food waste chain** [7]

|  |  |  |  |
| --- | --- | --- | --- |
| **Processes** | **N budgets** | **Methods** | **Parameters** |
| Final Disposal | The nitrogen contents of food *N* *food* | *Wfood waste×Ni* | See Table.S5. |
| Food Processing | The nitrogen loss during food processing *N**w-processing* | *N* *food*$×$k1 | k1 = 0.36 |
| Food Production | The nitrogen loss related to farmland runoff *N**runoff* | *N* *crop-food* $×$k2 | k2 =2.86 |
| The nitrogen loss related to farmland erosion *N**erosion* | *N* *crop-food* $×$k3 | k3 =0.14 |
| The nitrogen accumulation in farmland *N**accumulation* | *N* *crop-food* $×$k4 | k4 =0.14 |
| NH3 emissions from farmland | *N* *crop-food* $×$k5 | k5 =2.71 |
| N2O emissions from farmland | *N* *crop-food* $×$k6 | k6 =0.14 |
| N2 emissions from farmland | *N* *crop-food* $×$k7 | k7 =2.29 |
| NH3 emissions from livestock | *N* *livestock* $×$k8 | k8 =5.50 |
| N2O emissions from livestock | *N* *livestock* $×$k9 | k9 =0.25 |
| N2 emissions from livestock | *N* *livestock* $×$k10 | k10 =1.00 |
| N emissions from livestock’s manure waste *N**manure-waste* | *N* *livestock* $×$k11 | k11 =7.50 |
| The usage of fertilizer *N**u-fertilizer* | *N* *crop-food* $×$k12 | k12 =8.71 |
| Fertilizer Production | The nitrogen loss related to fertilizer production *N**w-fertilizer* | *N* *u-fertilizer* $×$k13 | k13 =0.15 |

Notes: In our research, the crop food include staple food, vegetables, soy food, nuts and fruits; the livestock include meats, eggs and sea food.

**Table. S7. The phosphorus contents of different food (P*i*，kg/kg)** [8]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Rice** | **Wheat** | **Other Cereals** | **Beans** | **Vegetables** | **Nut** | **Fruit** |
| 0.00254 | 0.00381 | 0.00314 | 0.00605 | 0.00063 | 0.00414 | 0.00025 |
| **Pork** | **Beef** | **Mutton** | **Poultry** | **Other Meat** | **Seafood** | **Egg** |
| 0.00560 | 0.0021 | 0.0016 | 0.00150 | 0.00176 | 0.00256 | 0.00260 |

Notes: In our research, we aggregated the 12 categories of food into 8 categories: staple food, vegetables, meats, sea food, eggs, soy food, nuts and fruits. The phosphorus content of staple food is the average of rice, wheat and other cereals; The phosphorus contents of meats is the average of pork, beef, mutton, poultry and other meat.

**Table. S8. The P budget and use efficiencies for different processes of food waste chain** [8]

|  |  |  |  |
| --- | --- | --- | --- |
| **Processes** | **P budgets** | **Methods** | **Parameters** |
| Final Disposal | The phosphorus contents of food *P* *food* | *Wfood waste×Pi* | See Table. S7. |
| Food Processing | The phosphorus loss during food processing *P**w-processing* | *P* *food*$×$k1 | k1 = 0.36 |
| Food Production | The phosphorus loss related to farmland runoff *P**runoff* | *P* *crop-food* $×$k2 | k2 =0.18 |
| The phosphorus loss related to farmland erosion *P**erosion* | *P* *crop-food* $×$k3 | k3 =0.45 |
| The phosphorus accumulation in farmland *P**accumulation* | *P* *crop-food* $×$k4 | k4 =4.15 |
| P emissions from livestock’s manure waste *P**manure-waste* | *P* *livestock* $×$k5 | k11 =18.00 |
| The usage of fertilizer *P**u-fertilizer* | *P crop-food* $×$k6 | k6 =6.23 |
| Fertilizer Production | The phosphorus loss related to fertilizer production *P**w-fertilizer* | *P* *u-fertilizer* $×$k7 | k7 =0.15 |

Notes: In our research, the crop food include staple food, vegetables, soy food, nuts and fruits; the livestock include meats, eggs and sea food.

**Table** **S9 Comparison of food waste between our study and other ones across the world**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Country** | **Wasted food****g/cap/meal** | **consumers** | **Description** | **Source** |
| China | 56 | Cadres and staff | Buffet, a total of 656 samples were surveyed in 4 workplace canteens in Beijing, included breakfast, lunch and dinner, adopted direct weighing | This study |
| China | 61 | University students | Non-buffet, a total of 9192 samples were surveyed in Chinese 29 university canteens across 29 provinces, considered only lunch and dinner, adopted direct weighing |  [9] |
| China | 77 | University students | Non-buffet, a total of 1612 samples were surveyed in 7 university canteens in Wuhan, considered only lunch and dinner, adopted direct weighing | [10] |
| China | 74 | University students | Non-buffet, a total of 551 samples were surveyed in 6 university canteens in Beijing, considered only lunch and dinner, adopted direct weighing |  [11] |
| China | 130 | Students | Buffet and non-buffet, a total of 998 samples were surveyed at lunch time in 6 schools in Beijing, adopted weighing | [12] |
| China | 116 | Tourists and local residents | Buffet, a total of 360 meals were surveyed in a restaurant in Taiwan, adopted weighing | [13] |
| China | 93 | Tourists and local residents | Non-buffet, a total of 3145 tables were surveyed in 195 restaurants in four cities (Beijing, Shanghai, Lhasa, Chengdu), adopted direct weighing | [14] |
| China | 74 | Tourists and local residents | Non-buffet, a total of 2564 dining-tables were surveyed in 124 restaurants in Beijing, adopted direct weighing | [7] |
| Portugal | 69 | Staff in Municipality | Non-buffet, a total of 160 meals were surveyed at Lunch time in A workplace in North of Portugal, adopted direct weighing | [15] |
| France | 73 | Staff and university students | Buffet, a total of 479 meals were surveyed at Lunch time in a workplace cafeteria, weighing | [16] |
| Portugal | 76.5 | University students | Non-buffet, a total of 2871 meals were surveyed at Lunch time in A university’s canteen in Lisbon, direct weighing |  [17] |
| United States | 78 | University students | Buffet, surveyed at lunch time in 2 University’s dining halls in Champaign, adopted direct weighing | [18] |
| United States | 233 | Students and Faculty | Non-buffet, surveyed at Lunch time in a private school located in Columbia, adopted direct weighing | [19] |
| Italy | 141 | Students | Non-buffet, surveyed in 18 school in Cento, Visual assessment |  [20] |
| Sweden | 25 | Students | Buffet, a total of 2939 meals were surveyed at Lunch time in 14 schools in Sala, weighing | [21] |
| United Kingdom | 155 | Tourists and local residents | Non-buffet, a total of 4668 guests were surveyed in an ethnic food restaurant in UK, adopted weighing | [22] |
| Iraq | 38 | Tourists and local residents | surveyed in 18 restaurants in four cities（Babel、Tikrit、Mosul and Al-Muthanna, direct weighing | [23] |
| Thailand | 35.1 | Tourists and local residents | Non-buffet, a total of178 guests were surveyed in one restaurant in Chiang Rai, direct weighing | [24] |

References

1. US Department of Agriculture. Food yields: summarized by different stages of preparation. Washington D C: USDA Agriculture Research Service, **1975**.
2. US Department of Agriculture. USDA table of cooking yields for meat and poultry. Maryland: USDA Agriculture Research Service Beltsville Human Nutrition Research Center Nutrient Data Laboratory, **2012**.
3. Cao, S.; Xie, G.; Chen, W.; Guo, H. Ecological Footprint of Raw and Derived Agricultural Products. **2014**, *J. Nat. Recour.* 29, 1336–1344.
4. Zhang, D.; Cheng, S.; Gao, L.; Cao, X.; Liu, X.; Liu, Y.; Bai, J.; Yu, W., Ecological footprint of catering industry food waste in Beijing. *Resour. Sci.* **2016a**, 38 (01): 10-18.
5. Wu, Y.; Wang, X.; Lu, F. Ecological Footprint and Water Footprint of Food Consumption in Beijing. **2011**, *Resour. Sci.* 33(6), 1145-1152.
6. Zhang, D.; Cheng, S.; Gao, L.; Liu, X.; Cao, X.; Liu, Y.; Bai, J.; Xu, S.; Yu, W.; Qin, Q. The carbon footprint of catering industry food waste: a Beijing case study., **2016b**, *Acta Ecol. Sin.* 36 (18): 5937-5948.
7. Zhang, D.; Lun, F.; Cheng, S.; Liu, X.; Cao, X.; Liu, Z. The nitrogen footprint of different scales of restaurants of food waste: a Beijing case study. **2017**, *Acta Ecol. Sin.* 37 (05): 1699-1708.
8. Zhang, D.; Lun, F.; Cheng, S.; Gao, L.; Liu, X.; Cao, X.; Qin, Q.; Liu, Y.; Bai, J.; Xu, S.; Yu, W. The phosphorus footprint and its environmental analysis for restaurant food waste: taking Beijing as an example. *J. Nat. Recour.* **2016c**,31 (05): 812-821.
9. Qian, L.; Li, F.; Cao, B.; Wang, L.; Jin, S. Determinants of food waste generation in Chinese university canteens: Evidence from 9192 university students. *Resour. Conserv. Recycl.* **2021**, 167, 105410.
10. Zhang, H.; Li, S.; Wei, D.; He, J.; Chen, J.; Sun, C.; Vuppaladadiyam, A.K.; Duan, H. Characteristics, environmental impact, and reduction strategies of food waste generated by young adults: Case study on university canteens in Wuhan, China. *J. Clean Prod.* **2021**, 321, 128877.
11. Wu, Y.; Tian, X.; Li, X.; Yuan, H.; Liu, G. Characteristics, influencing factors, and environmental effects of plate waste at university canteens in Beijing, China. *Resour. Conserv. Recycl.* **2019**, 149, 151-159.
12. Liu, Y.; Cheng, S.; Liu, X.; Cao, X.; Xue, L.; Liu, G. Plate Waste in School Lunch Programs in Beijing, China. *Sustainability*. **2016**, 8, 1288.
13. Yi-Chi Chang, Y.; Lin, J.; Hsiao, C. Examining effective means to reduce food waste behaviour in buffet restaurants. *Int. J. Gastron. Food Sci.* **2022**, 29, 100554.
14. Wang, L.; Liu, G.; Liu, X.; Liu, Y.; Gao, J.; Zhou, B.; Gao, S.; Cheng, S. The weight of unfinished plate: A survey-based characterization of restaurant food waste in Chinese cities. *Waste Manage.* **2017**, 66, 3-12.
15. Pires, I.; Machado, J.; Rocha, A.; Liz Martins, M. Food Waste Perception of Workplace Canteen Users—A Case Study. *Sustainability*. **2022**, 14, 1324.
16. Sebbane, M.; Costa, S. Food leftovers in workplace cafeterias: An exploratory analysis of stated behavior and actual behavior. *Resour. Conserv. Recycl.* 2018, 136, 88-94.
17. Pinto, R.S.; Pinto, R.M.D.S.; Melo, F.F.S.; Campos, S.S.; Cordovil, C.M. A simple awareness campaign to promote food waste reduction in a university canteen. *Waste Manage.* **2018**, 76, 28-38.
18. Ellison, B.; Savchenko, O.; Nikolaus, C.J.; Duff, B.R.L. Every plate counts: Evaluation of a food waste reduction campaign in a university dining hall. *Resour. Conserv. Recycl.* **2019**, 144, 276-284.
19. García-Herrero, L.; Costello, C.; De Menna, F.; Schreiber, L.; Vittuari, M. Eating away at sustainability. Food consumption and waste patterns in a US school canteen. *J. Clean Prod.* **2021**, 279, 123571.
20. García-Herrero, L.; De Menna, F.; Vittuari, M. Food waste at school. The environmental and cost impact of a canteen meal. *Waste Manage*. **2019**, 100, 249-258.
21. Eriksson, M.; Persson Osowski, C.; Malefors, C.; Björkman, J.; Eriksson, E. Quantification of food waste in public catering services – A case study from a Swedish municipality. *Waste Manage*. **2017**, 61, 415-422.
22. Filimonau, V.; Nghiem, V.N.; Wang, L. Food waste management in ethnic food restaurants. *Int. J. Hosp. Manag.* **2021**, 92, 102731.
23. Filimonau, V.; Algboory, H.; Mohammed, N.K.; Kadum, H.; Qasem, J.M.; Muhialdin, B.J. Food waste and its management in the foodservice sector of a developing economy: An exploratory and preliminary study of a sample of restaurants in Iraq. *Tour. Manag. Perspect.* **2023**, 45, 101048.
24. Junkrachang, P.; Butcher, K.; Yodsuwan, C. Investigating guest reactions to plate waste reduction strategies: A field experiment in a casual-dining restaurant. Int. J. Hosp. Manag. 2024, 121, 103805.