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Effect of Chinese steamed bun and bread processing on pesticide residues in wheat flour

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Abstract

The changes of five pesticides including imidacloprid, triadimefon, fenitrothion, chlorpyrifos-methyl, and chlorpyrifos in wheat flour during Chinese steamed bun and bread processing were systematically investigated. The pesticide residues were determined by high performance liquid chromatography coupled with diode array detector. Dough mixing step in both Chinese steamed bun and bread processing reduced the concentration of five pesticide residues significantly by 33 to 46%. It was mainly attributed to the increase of moisture content in mixed dough during this step. The reduction of pesticides in fermenting step varied from 2 to 22% in Chinese steamed bun and bread processing. Resting step in both Chinese steamed bun and bread processing has little effect on the pesticide residues with the reduction from 2 to 8%. The five pesticides have different behaviours in steaming step of Chinese steamed bun processing and in baking step of bread processing. During the steaming step, only the concentrations of triadimefon and imidacloprid residues in crust were increased by 52 and 1%, the others in crust and in crumb of Chinese steamed bun were decreased by 4 to 38%. After the baking step, the concentrations of triadimefon and imidacloprid residues in crust, and the triadimefon residue in crumb of bread were increased by 65, 83, and 14%, respectively, the others were all reduced. The processing factors (PFs) for triadimefon and imidacloprid in crust in the steaming and baking steps, for triadimefon in crumb in the baking steps were greater than 1, and the others were all less than 1. Overall, this study provides important references for monitoring pesticide residues in the processing of wheat flour products. The PFs obtained could be helpful for the risk assessment of pesticides in wheat flour products.

Keywords: Wheat flour, Chinese steamed bun, Bread, Pesticide, Processing factor

Introduction

Wheat is the most widely grown crop in the world, and the second most important food crop after rice. It provides 20% of the daily protein for 4.5 billion people (Qin et al., 2015). China is the world's leading producer of wheat, cultivating a total of more than 130 million tons in 2020, followed by India, Russia, American, Canada, and Australia (FAO, Food and Agriculture Organization, 2020). In addition, China is also the largest consumer of wheat worldwide, accounting for 19% of global wheat consumption in marketing year 2020/21 (July–June) (OECD-FAO, Organisation for Economic Co-operation and Development, 2021). Wheat flour produced from wheat can be used as a key source to make many foods, including baking products, steaming products, boiling products, and so on. Chinese steamed bun, also called as Mantou, is a traditional and basic staple food in northern part of China and popular in every place of China. Nowadays, bread as an important food to the westerners has becoming more and more popular in China.

Pesticides are applied inevitably in crops to protect crops against pest damage and diseases, especially in wheat. Pesticides play a major role in improving wheat yield and quality (Brauns et al., 2018; Zhao et al., 2014).

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Nonetheless, pesticides also carry hazards as residues accumulated in different wheat grain fractions. Positive findings of pesticides in wheat flour have been reported now and then according to many studies, some of which were even higher than the permissible limits prescribed by World Health Organization/Food and Agriculture Organization of the United Nations (WHO/FAO) (Neela et al., 2004). The adverse effects of pesticides have become increasingly prominent. Triadimefon, imidacloprid, fenitrothion, chlorpyrifos-methyl and chlorpyrifos are among the most frequently found pesticides in wheat flour according to literatures (Bordin et al., 2017; Dasriya et al., 2021; Watanabe et al., 2018).

Apart from the residue level of pesticides in wheat flour, the safety of wheat flour products is also influenced greatly by different processing methods (Bajwa & Sandhu, 2014). According to the literature, many studies have focused on the effects of processing on the pesticide residues in fruits and vegetables, including various processing steps like washing, pickling, drying, and canning etc. (Liang et al., 2014; Yigit & Velioglu, 2020). Up to now, very few existing literatures focus on the effects of processing on the pesticide residues in wheat flour (Duan et al., 2022; Umran et al., 2009). Only Yu et al. (2021) investigated the fate of chlorpyrifos, omethoate, cypermethrin, and deltamethrin during Chinese steamed bun processing, and only Sharma et al. (2005) reported the dissipation of six pesticides including hexaconazole, propiaconazole, malathion, chlorpyriphos and deltamethrin during bread processing. Considering the variety of pesticides may be applied on wheat and the potential health and safety risk of pesticide residues in Chinese steamed bun and bread, a special emphasis should be given to understand the effect of Chinese steamed bun and bread processing on pesticide residues in wheat flour.

The present study investigated the effect of Chinese steamed bun and bread processing on five common pesticides including triadimefon, imidacloprid, fenitrothion, chlorpyrifos-methyl and chlorpyrifos in wheat flour. Moreover, processing factors were also calculated for each processing step. The findings obtained in this study will contribute to the establishment of Maximum Residue Limits (MRLs) for wheat products and the risk assessment of pesticide residues in wheat products for consumers.

Materials and methods

Reagents and materials

Standards of triadimefon ($C_{14}H_{16}ClN_3O_2$, CAS 43121-43-3), imidacloprid ($C_9H_{10}ClN_5O_2$, CAS 138261-41-3), fenitrothion ($C_9H_{12}NO_5PS$, CAS 122-14-5), chlorpyrifos-methyl ($C_7H_7Cl_3NO_3PS$, CAS 5598-13-0), and chlorpyrifos ($C_9H_{11}Cl_3NO_3PS$, CAS 2921-88-2) (purity $\geq$95.0%) were purchased from Dr. Ehrenstorfer (Augsburg, Germany). Acetonitrile (HPLC grade) was obtained from Merck (Darmstadt, Germany). Analytical reagent sodium chloride (NaCl) and anhydrous magnesium sulfate ($MgSO_4$) were purchased from Shanghai Yuanye Bio-Technology Co., Ltd. (Shanghai, China). Octadecylsilane (C_{18}) and primary secondary amine (PSA) were obtained from Shanghai Jiyi Bio-Technology Co., Ltd. (Shanghai, China).

Sample preparation and processing

The blank wheat flour was obtained from local market and tested to confirm the absence of target pesticides. The blank wheat flour was spiked by blending the mixed standard stock solutions of the five pesticides to achieve the residue level of approximately 3 mg kg^{-1}. The spiked wheat flour was retained in the fume cupboard for 24 h to allow the pesticides to adhere to the wheat flour and remain in the wheat flour in a stable manner.

According to the survey of food companies and literatures, Chinese steamed bun processing and bread processing have similar steps such as dough mixing, fermenting, shaping and resting at different temperature and time. The processing steps of Chinese steamed bun and bread were shown in Fig. 1 with sampling points.

The Chinese steamed bun was produced according to Chinese Standard (LS/T 3204, 1993) with the details are as follows:

Dough mixing: The wheat flour of 1000 g and active dry yeast of 10 g were mixed with 480 mL distilled water using M10-MC91 flour-mixing machine (Joyoung Co., Ltd., Jiaxing, China) to obtain the dough with moisture content (MC) of 40–42%.
Fermenting: The dough was fermented in a fermentation cabinet at 38 °C for 60 min.
Shaping: The dough was kneaded for 3 min to form into round small dough pieces with smooth surface.
Resting: The dough was rested at 38 °C for 15 min.
Steaming: The rested dough was put into a steamer when water was boiling and steamed for 20 min, followed by cooling at room temperature for 40–60 min. The crust and the crumb were taken separately to determine the pesticide residues.

The bread was produced according to Chinese Standard (GB/T 14611–2008, 2008) with slight modifications:

Dough mixing: The wheat flour of 1000 g was mixed with 10 g active dry yeast, 60 g sugar, 15 g salt, and 480 mL distilled water using M10-MC91 flour-mixing machine (Joyoung Co., Ltd., Jiaxing, China) to obtain the dough with MC of 40–42%.

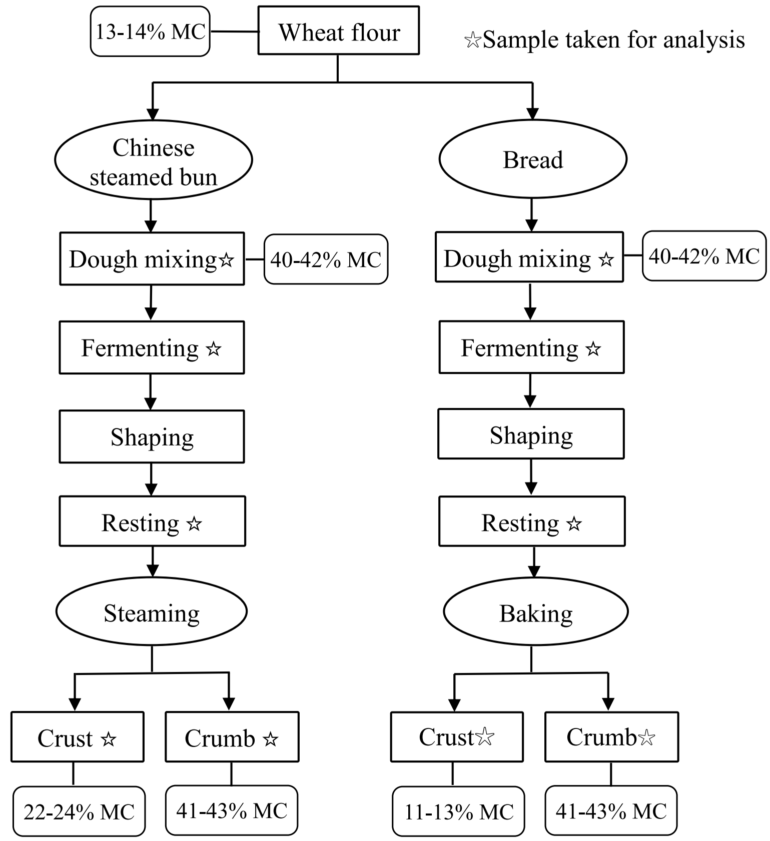

Fig. 1 Processing steps of Chinese steamed bun and bread production with sampling points

Fermenting: The dough was fermented in a fermentation cabinet at 30 °C for 90 min, the dough was taken and pressed to remove bubbles when fermented for 55 min.

Shaping: The dough is pressed into a long sheet using a dough press kit, then rolled up and placed in a mold.

Resting: The mold containing dough was rested at 30 °C for 45 min.

Baking: The oven was preheated to 220 °C, the upper and lower temperatures were adjusted to 180 °C and 220 °C, respectively. The dough was baked for 20 min. The crust and the crumb were taken separately to determine the pesticide residues.

Extraction and purification

The extraction and purification procedures were described by Duan et al. (2022). Briefly, 5.0 g homogenized sample was weighed into 50 mL centrifuge tube with 10.0 mL ultra-pure water added. The tube was shaken on a DMT-2500 multi-tube vortexer (Zigui Instrument Co., Ltd., Shanghai, China) for 10 min. Then, 10.0 mL acetonitrile was added into the tube and shaken for 30 min at 2500 rpm/min. After the adding of 4.0 g anhydrous $MgSO_4$ and 1.0 g NaCl, the mixture was shaken for 2 min and centrifuged for 5 min at 6700 g. Next, 6.0 mL supernatant was taken and blown to dryness under nitrogen, then dissolved in 0.6 mL acetonitrile. After the addition of 100 mg PSA and 100 mg C_{18} (Liu et al., 2022), the mixture was shaken vigorously for 1 min, and then centrifuged for 8 min at 9600 g. The supernatant was filtered with 0.22 μm nylon syringe filters for high performance liquid chromatography (HPLC) analysis.

HPLC analytical conditions

The separation and quantification were carried out using Agilent 1200 Series HPLC system (Agilent, CA, USA) (Duan et al., 2022). Chromatographic separation was achieved by gradient elution using the Agilent Extend-C_{18} column (250 mm × 2.1 mm, 5 mm). The column temperature was optimized and set at 25 °C. Gradient elution was performed with water as mobile phase A and acetonitrile as mobile phase B. The gradient elution program was as follows: 0–4.5 min, 40% B; 4.5–10.5 min, 50% B; 10.5–29 min, 60% B; 29–40 min, 70% B; 40–45 min, 40%

B. The flow rate was 1 mL min^{-1}. Analysis of pesticides was carried out on G1315C Diode array detector (DAD) with wavelength set at 216 nm for triadimefon, imidacloprid, and fenitrothion, 230 nm for chlorpyrifos-methyl and chlorpyrifos (Wu et al., 2010). All data were acquired employing Agilent Quantitative Analysis data processing software.

Processing factors calculation

According to the Joint FAO/WHO Meeting on Pesticide Residues (JMPR), the processing factor (PF) is generally used to evaluate the effect of food processing on pesticide residues (FAO, Food and Agriculture Organization, 2006). The PFs are calculated by the ratio of the residue levels in processed commodities and the commodities to be processed. PF less than 1 means a decrease in residue level during processing, while PF greater than 1 indicates an increase in residue level during the processing step (Scholz et al., 2018).

Statistical analysis

All tests were performed in quintuplicate and the values presented are means ± standard deviation (SD) of five replicates. Data were evaluated by one-way ANOVA analysis with SPSS base 22.0 software and the least significant difference (LSD) test was utilized to determine the differences and a value of $p < 0.05$ was considered significant.

Results and discussion

Method validation

The validation parameters of the analytical methodology are shown in Table 1. The linearity study showed that the correlation coefficients (R^2) of the calibration curves obtained in the range of 0.25–10 μg mL^{-1} were higher than 0.9995 for five pesticides. The limit of detections (LODs) and limit of quantifications (LOQs) were calculated as three times and ten times of the signal-to-noise (S/N) of blank sample and in the range of 0.0079–0.0363 mg kg^{-1} and 0.0463–0.144 mg kg^{-1}, respectively. To evaluate the accuracy and precision of the method, recovery experiments were conducted on wheat flour at three spiked levels (0.05, 0.5, and 3.0 mg kg^{-1}) with five replications. The mean recoveries for all pesticides were in the range of 80% ~ 110% with relative standard deviations (RSDs) below 10%. It was confirmed that the method was sufficiently reliable for pesticide analysis in this study (CAC, Codex Alimentarius Commission., 2017).

Effects of Chinese steamed bun processing on the pesticide residues

The initial concentration of the targeted pesticides was determined in wheat flour previous to the processing. Table 2 showed the residues of the five pesticides in samples during Chinese steamed bun and bread processing. As shown in Table 2, the concentrations of triadimefon, imidacloprid, fenitrothion, chlorpyrifos-methyl, and chlorpyrifos showed significant changes compared with wheat flour during Chinese steamed bun and bread processing.

Dough mixing is the first and basic step of Chinese steamed bun processing. Compared to the initial wheat flour concentration, the pesticide residues in mixed dough were reduced significantly by 46, 41, 39, 33, and 36% for triadimefon, imidacloprid, fenitrothion, chlorpyrifos-methyl, and chlorpyrifos, respectively (p<0.05). The mixed dough was formed by wheat flour and distilled water with MC increased from 13–14% to 38–40%. It can be assumed that the reduction of the concentration of pesticide residues in dough mainly relate to the increase of MC, which was in accordance with Zhang et al. (2020).

Similar with other fermented flour products, fermentation is a crucial step in the processing of Chinese steamed bun. The mixed dough was subjected to fermenting step for 60 min at 38 °C. After fermenting, the pesticide residues were reduced by 10, 9, 14, 18, and 5% for triadimefon, imidacloprid, fenitrothion, chlorpyrifos-methyl and chlorpyrifos, respectively. Similar results were reported by Yu et al. (2021), in which organophosphorus pesticides including chlorpyrifos and omethoate showed lower concentrations in fermented dough. The reduction of pesticide residues during fermentation might be attributed to

Table 1 Calibration curve coefficients (R^2), LODs, LOQs, Mean recoveries ± RSDs ($n = 5$) for five pesticides in wheat flour

Pesticides	R^2	LOD (mg kg^{-1})	LOQ (mg kg^{-1})	Mean recovery (%) ± RSD		
				0.05 mg kg^{-1}	0.1 mg kg^{-1}	3.0 mg kg^{-1}
Triadimefon	0.9998	0.0268	0.1058	107.41 ± 7.83	87.78 ± 0.98	80.81 ± 3.55
Imidacloprid	0.9997	0.0079	0.0463	94.51 ± 9.08	89.13 ± 7.72	80.66 ± 4.76
Fenitrothion	0.9999	0.0231	0.0844	108.24 ± 2.06	105.22 ± 6.68	96.90 ± 3.64
Chlorpyrifos-methyl	0.9998	0.0360	0.1220	102.31 ± 4.85	98.02 ± 6.87	81.45 ± 5.32
Chlorpyrifos	0.9997	0.0363	0.1440	105.79 ± 9.70	84.77 ± 9.14	82.91 ± 2.62

Table 2 Residues of five pesticides (mg kg^{-1}) in samples during Chinese steamed bun and bread processing ($n = 5$)

Treatment	Sample	Pesticide (mean ± SD)				
		Triadimefon	Imidacloprid	Fenitrothion	Chlorpyrifos-methyl	Chlorpyrifos
Chinese steamed bun processing	Spiked wheat flour	$3.01^{a} \pm 0.067$	$3.26^{a} \pm 0.053$	$3.10^{a} \pm 0.055$	$2.93^{a} \pm 0.030$	$2.77^{a} \pm 0.058$
	Mixed dough	$1.63^{b} \pm 0.058$	$1.93^{b} \pm 0.116$	$1.88^{b} \pm 0.034$	$1.96^{b} \pm 0.043$	$1.78^{b} \pm 0.014$
	Fermented dough	$1.47^{bc} \pm 0.026$	$1.76^{bc} \pm 0.037$	$1.62^{c} \pm 0.048$	$1.61^{c} \pm 0.039$	$1.69^{bc} \pm 0.045$
	Rested dough	$1.40^{c} \pm 0.058$	$1.71^{bc} \pm 0.017$	$1.56^{c} \pm 0.040$	$1.60^{c} \pm 0.040$	$1.66^{bc} \pm 0.051$
	Chinese steamed bun crust	$2.13^{d} \pm 0.021$	$1.80^{bc} \pm 0.007$	$1.14^{d} \pm 0.060$	$0.99^{d} \pm 0.114$	$1.60^{c} \pm 0.048$
	Chinese steamed bun crumb	$1.34^{c} \pm 0.019$	$1.62^{c} \pm 0.061$	$1.21^{d} \pm 0.064$	$1.09^{d} \pm 0.029$	$1.59^{c} \pm 0.035$
Bread processing	Spiked wheat flour	$3.01^{a} \pm 0.067$	$3.26^{a} \pm 0.053$	$3.10^{a} \pm 0.055$	$2.93^{a} \pm 0.030$	$2.77^{a} \pm 0.058$
	Mixed dough	$1.65^{b} \pm 0.086$	$1.82^{b} \pm 0.010$	$1.67^{b} \pm 0.064$	$1.74^{b} \pm 0.030$	$1.64^{b} \pm 0.027$
	Fermented dough	$1.28^{c} \pm 0.074$	$1.65^{bc} \pm 0.034$	$1.63^{b} \pm 0.075$	$1.58^{c} \pm 0.024$	$1.50^{bc} \pm 0.053$
	Rested dough	$1.26^{c} \pm 0.140$	$1.51^{c} \pm 0.063$	$1.57^{b} \pm 0.073$	$1.52^{c} \pm 0.012$	$1.44^{cd} \pm 0.006$
	Bread crust	$2.08^{d} \pm 0.024$	$2.77^{d} \pm 0.007$	$0.36^{c} \pm 0.067$	$0.31^{d} \pm 0.095$	$1.40^{cd} \pm 0.081$
	Bread crumb	$1.44^{bc} \pm 0.063$	$1.46^{c} \pm 0.124$	$0.90^{d} \pm 0.090$	$0.82^{e} \pm 0.126$	$1.31^{d} \pm 0.068$

a-e: Values within the same column in Chinese steamed bun and bread production with different letters are significantly different ($p < 0.05$)

biological degradation caused by the activity of microbes according to previous studies (Han et al., 2017; Quan et al., 2020).

Shaping step is indispensable step to shape the Chinese steamed bun. The time of this step is short with no change of temperature and moisture. Therefore, no sampling point in shaping step. Resting is secondary fermentation and the shaped dough was rested for 15 min at 38 °C. The residue levels of five pesticides were decreased slightly by 1 to 5% with no significant differences ($p > 0.05$) after resting step.

Steaming is the unique step in Chinese steamed bun processing. The pesticides have different behavior in steaming steps. The increase of 52 and 1% for the concentration of triadimefon and imidacloprid were observed, while the levels of fenitrothion, chlorpyrifos-methyl, and chlorpyrifos were reduced by 4 to 38% in the crust of Chinese steamed bun. In the crumb of Chinese steamed bun, the concentrations of pesticides were decreased by 4, 5, 22, 32, and 4% for triadimefon, imidacloprid, fenitrothion, chlorpyrifos-methyl and chlorpyrifos, respectively. The MC was changed from 40–42% to 22–24% in crust and 41–43% in crumb of Chinese steamed bun after steaming. Taking the MC into account, it can be deduced that the concentrate plays more important role than thermal evaporation or degradation on triadimefon and imidacloprid in the crust of Chinese steamed bun. It may be due to the lower vapor pressures of triadimefon (1.50×10^{-8} mmHg) and imidacloprid (7.00×10^{-12} mmHg) than fenitrothion (5.40×10^{-5} mmHg), chlorpyrifos-methyl (2.25×10^{-5} mmHg), and chlorpyrifos (2.02×10^{-5} mmHg), which was in accordance with Duan et al. (2022).

Effects of bread processing on the pesticide residues

The pesticide residues in sample taken from the production of bread are presented in Table 2. Similar with the Chinese steamed bun processing, dough mixing is the first and basic step of bread processing. The concentrations of five pesticides in mixed dough were reduced significantly by 41 to 46% (p<0.05). The results of dough mixing step in bread processing were very close to Chinese steamed bun processing. The reduction of the concentration of pesticide residues in dough was mainly related to the increase of MC.

During the fermenting step in bread processing, the dough was fermented at lower temperature (30 °C) for longer time (90 min) than in Chinese steamed bun processing. The pesticide residues were reduced by 22, 9, 2, 9, and 9% for triadimefon, imidacloprid, fenitrothion, chlorpyrifos-methyl and chlorpyrifos, respectively. Many factors could affect the fate of pesticides during food fermentation, such as chemical structure, volatility, adsorption ability, biodegradation of microorganisms, and so on (Bayarri et al., 2015; Quan et al., 2020). These factors are dependent on many environmental parameters, including processing temperature, moisture content, time, and additives (Azizi & Homayouni, 2009). The five pesticide residues in fermenting step during bread processing showed different reductions compared with Chinese steamed bun processing, which may be due to the different fermenting temperature, fermenting time, and additives of sugar and salt.

The shaped dough after fermenting was rested for 45 min at 30 °C. The residue levels of five pesticides were decreased slightly by 2 to 8% with no significant differences (p>0.05) after resting step. The results were very close to the situations of resting during Chinese steamed bun processing.

Baking is the unique step in bread processing. During baking, the MC were changed from 40–42% to 11–13% in crust and 41–43% in crumb of bread. The concentrations of triadimefon and imidacloprid were increased significantly by 65 and 83% in crust of bread (p<0.05), while fenitrothion, chlorpyrifos-methyl and chlorpyrifos were reduced by 77, 80, and 3%, respectively. In crumb of bread, only the concentration of triadimefon was increased by 14%, the others were all decreased. It can be considered that the concentrate plays more important role than thermal evaporation or degradation on triadimefon and imidacloprid in crust and on triadimefon in crumb of bread. The vapor pressures of pesticides were closely related to the thermal evaporation of pesticides during heating, which was in agreement with Sharma et al. (2005).

Processing factors for Chinese steamed bun and bread processing

The PFs were used by JMPR to evaluate the effect of food processing step on pesticide residues. The PFs of five pesticides for different processing steps during Chinese steamed bun and bread production were presented in Table 3. The processing steps resulted in different behaviors of pesticides during production.

The PFs of five pesticides for dough mixing, fermenting and resting during Chinese steamed bun processing were approximately the same as bread processing. The dough mixing step in Chinese steamed bun processing reduced the concentration of pesticide residues with PFs ranging from 0.54 to 0.67, while in bread processing ranging from 0.54 to 0.59. The decreases of the concentration of pesticides were mainly attributed to the increase of MC. The PFs of five pesticides for fermenting during Chinese steamed bun processing were from 0.82 to 0.95, while from 0.78 to 0.98 during bread processing. The resting in Chinese steamed bun processing and bread processing had little effect on the reduction of pesticides with PFs closing to 1. Only the PFs of triadimefon and imidacloprid in Chinese steamed bun crust for steaming, in bread crust for baking, and triadimefon in bread crumb for baking were higher than 1, the others were all less than 1. On account of different characteristics of pesticides like vapor pressure, the concentrate and thermal evaporation or degradation have different effect on pesticides during steaming or baking, which was in agreement with Li et al. (2021).

The PFs are indispensable for risk assessment of actual pesticide residues in food commodities and play an important role in recommending and amending MRLs for processed products (González-Rodríguez et al., 2011). Although thousands of PFs have been derived from many experiments, there is still not enough for risk assessment in consideration of numerous pesticides and food products with different processing steps (Scholz et al., 2018). The PFs obtained in this study could be helpful for monitoring pesticide residues during Chinese steamed bun and bread processing and protecting the public health from pesticide contamination.

Conclusion

The effect of processing steps of Chinese steamed bun and bread production on triadimefon, imidacloprid, fenitrothion, chlorpyrifos-methyl and chlorpyrifos residues was systematically investigated in the study. Dough mixing step reduced the concentration of five pesticides significantly, which was mainly attributed to the increase of MC during this step. The reduction of pesticides in

Table 3 Processing factors of the five pesticides for different processing steps

Treatment	Processing step	Pesticides				
		Triadimefon	Imidacloprid	Fenitrothion	Chlorpyrifos-methyl	Chlorpyrifos
Chinese steamed bun processing	Dough mixing	0.54	0.59	0.61	0.67	0.64
	Fermenting	0.90	0.91	0.86	0.82	0.95
	Resting	0.95	0.98	0.96	0.99	0.98
	Steaming for Chinese steamed bun crust	1.52	1.05	0.73	0.62	0.96
	Steaming for Chinese steamed bun crumb	0.96	0.94	0.78	0.68	0.96
Bread processing	Dough mixing	0.55	0.56	0.54	0.59	0.59
	Fermenting	0.78	0.91	0.98	0.91	0.91
	Resting	0.98	0.92	0.96	0.96	0.96
	Baking for bread crust	1.65	1.83	0.23	0.21	0.97
	Baking for bread crumb	1.14	0.97	0.57	0.54	0.91

fermenting step varied in Chinese steamed bun and bread processing, while resting step has little effect on the decrease of pesticide residues. The pesticides have different behavior in steaming step for Chinese steamed bun processing and in baking step for bread processing. The triadimefon and imidacloprid residues in crust of Chinese steamed bun and bread, and the triadimefon residue in crumb of bread were increased in varying degrees. The others were decreased after steaming or baking step. The PFs of five pesticides for Chinese steamed bun and bread processing gained in this study could be helpful for the risk assessment of pesticides in wheat flour products, and the protection of public health from pesticide contamination.

Abbreviations

PFs: Processing factors; WHO/FAO: World Health Organization/Food and Agriculture Organization of the United Nations; MRLs: Maximum residue limits; C_{18}: Octadecylsilane; PSA: Primary secondary amine; MC: Moisture content; HPLC: High performance liquid chromatography; DAD: Diode array detector; JMPR: Joint FAO/WHO meeting on pesticide residues; SD: Standard deviation; LSD: Least significant difference; LODs: Limit of detections; LOQs: Limit of quantifications; S/N: Signal-to-noise; RSDs: Relative standard deviations..

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Authors' contributions

Y. Liang designed the experiments, analyzed the data of the experiments and drafted the manuscript. J. Duan collected and analyzed the data. Q. Gao helped to collect the data and draft the manuscript. Y. Li helped to design the experiments. Z. Zhang Reviewed and edited the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

All data supporting this study are included in this manuscript. Further details are available from the corresponding author upon request.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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