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# Aesthetic grading causes food losses without financially benefiting farmers: Micro-level evidence from China's fresh apple supply chain

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**Abstract**

International literature is lacking quantified information about the impact of raising demands for attractive appearances and the private standards on food loss and associated effects on the economy, the environment and social issues. Given the global scale and significance to food consumption and health, fresh apples were selected for researching the issues. By focusing on China, the major production region of fresh apple in the world where the effects of aesthetic preference and shape abnormality are substantial, the present study aims to gain insights into the on-farm grading processes and different marketing channels for fresh apples in China. It was discovered that 35% of the volume in China's major production areas of fresh apples were graded by aesthetic characteristics such as ripeness, colour, fragrance, bruising, intactness and appealing appearance. About 17.1% of production on average were considered as food losses mainly caused by such grading schemes. Favouring 'perfect' appearance; however, the grading did not yield economic benefits for smallholders. Lastly, direct procurement by supermarkets had a depressive effect on the price of fresh apples at the farm gate. The study has a unique value for global debates and actions against food loss and waste as it quantifies on-farm post-harvest losses of fresh apples by different agri-food chain organizations in China with respect to mass and economic value.

**Keywords**

Suboptimal food, postharvest losses, on-farm losses, fruit losses, smallholder farmers, economic losses

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## Introduction

Empirical evidence at global level on the environmental footprints of major commodity groups suggest that the production of fruits and vegetables relies on increasingly scarce resources such as soil and water (FAO, 2013; Mekonnen and Hoekstra, 2010). Compared with cereals, pulses and root crops, fruits and vegetables are hot spots for blue-water demand and carbon emissions. Thus, production of fresh fruits and vegetables (FFV) should be characterised by thoughtful use of resources, efficient supply chains and low levels of food loss and waste (FLW). Given the highly perishable nature, fruits and vegetables have higher levels of loss than other commodities such as cereals, pulses, meat and animal products, especially in situations where transport infrastructure, cold storage or processing conditions are inadequate.

More than half of fruits and vegetables in developing and emerging countries are lost in the supply chain before being consumed, but the reasons are variant. Relying on limited datapoints, FAO (2019) estimates that the global level of food losses for fruits and vegetables is 33%. In developing countries the rate is high up to 50%. Despite great regional variations, in the case of Eastern and South-eastern Asia, FLW for fruits and vegetables are caused mainly in the supply chain, for example storage (21%), transportation (8%), processing and packaging (12%), in addition to on-farm post-harvest operations (5%) and wholesale and retail (4%). In addition to these causes, significant quantities of fruits and vegetables that are fit for consumption are wasted along the food system because of aesthetic or physical irregularities. For fruits, the lost production could be valorised for human consumption by shifting to processing, social donation and direct selling at farm gate. Nevertheless, more than half of the sorted-out products were used for animal feed, anaerobic digestion, composting or land application or were not harvested at all (Roels and Van Gijseghem, 2017). Aesthetic grading (i.e. cosmetic grading) approaches result in a reduced economic value because of non-compliance with specific quality standards (e.g. Roels and Van Gijseghem, 2017) and is a perfect example for the importance of

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decisions and actions taken by different stakeholders along the food supply chain. Food that fails to meet these standards is either delegated to other purposes at a lower value or discarded, leading to both quantitative and qualitative loss (HLPE, 2014).

Despite the great societal costs, food loss associated with aesthetic grading were researched in anecdote or in qualitative manner while quantitative scientific research is insufficient. Relying on self-assessments, farmers' organisations and retailers in Germany indicated rejection rates due to cosmetic reasons at 20% on average with considerable variation, from 2% to 40% (De Hooge et al., 2018). In their study on Spanish persimmon producers, Fernandez-Zamudio et al. (2020) applied a quantitative direct measure on-site and found that farmers were not paid for an average of 16% of the total edible persimmon production as they were graded out on arrival at the cooperative warehouse and found to be unmarketable due to cosmetic standards. Roels and Van Gijseghem (2017) interviewed 300 horticulturists in Flanders/Belgium and were told two-thirds of them could not sell all of their products to intended sales channels due to cosmetic quality standards, leading to an average sales loss of about 10%.

On top of the knowledge gaps, limited evidence has been provided about the application of aesthetic grading at the value chain and potential development issues associated with smallholder farmers. A large volume of studies accepted losses as part of the marketing systems and explored alternative utilization paths without questioning the aesthetic standards (e.g. Allu and Belavina, 2020; Beausang et al., 2017; De Hooge et al., 2018; Johnson et al., 2019; Lu et al., 2022; Ludwig-Ohm et al., 2019; Peter et al., 2013; Redlingshöfer et al., 2017). Other authors focused on the improvement of pre-harvest and storage treatments in order to avoid infections, pests or storage losses (e.g. Jemric et al., 2006). Herzberg et al. (2023) found out that 15% of the total production in the field ready for harvest does not comply with the retailer's product requirements, while around 6% of the total production become food loss as no alternative marketing channel is available. Meyer et al. (2017) indicate that grading related to size, shape, colour etc. leads to a loss of 32% of apples sold in Germany. Furthermore, the respondents of their questionnaire rated the impact of retail specifications with the highest relevance among all other reasons for post-harvest losses in primary production. As homogeneous and 'perfect' produce (in terms of colour, shape, size, etc.) is mostly requested to facilitate trade at retail level (Cicatiello et al., 2016; Lee and Hayri Tongarlak, 2017), how do the application and compliance of such standards affect production and marketing at the farm gate? Despite a pyramid of studies on aesthetic preference and visually sub-optimal apples, these studies were mostly taken from consumer and expert perspectives (De Hooge et al., 2017; Jaeger et al., 2018). So far, there is almost no evidence about on-farm practices related to aesthetic grading for fruits or vegetables. From development perspectives, it is unknown if smallholder farmers in developing and emerging countries benefit from aesthetic standards. Only a few authors have examined the grades and standards applied to the ripeness, colour, fragrance, bruising, intactness and appealing appearance of agricultural commodities (Espinosa and Goodwin, 1991; Herzberg et al., 2023; Sterns and Reardon, 2002). Most of these studies explored agricultural standards that were specified by either technical authorities or private entities and investigated issues from the perspective of trade or that of consumers. Of the above studies, none has explored grades and standards that characterize agricultural commodities through aesthetic preference and examined the effects on the farm gate price. The key findings of this study have not ever been made in previous studies.

The aim of the present study was to gain insights into aesthetic standards and grading processes that are applied at the farm gate in the context of transforming agri-food chains in emerging economies. In particular, we examine the economic impacts of different grading schemes of fresh apples and compare the marketing effects of different chain organizations in China. The article starts with a literature review and a conceptual framework about aesthetic standards and chain governance. In Section 'Methodolody, survey and data' and 'Empirical Analysis and Research Findings', survey data, analytic methodology and research findings are introduced. In Section 'Discussions: Aesthetic grading, food losses and where next' and 'Conclusion', we discuss broader issues about food losses associated with aesthetic standards and grading and draw conclusions.

The study has great global and local implications for the food system transformation towards mitigated food losses and a variety of development issues associated with transforming agri-food chain towards vertical coordination. According to FAO statistics, apples contribute to 10% of the world fruit production behind bananas and plantains (18%) and watermelons (11%) (FAO, 2021). China is the largest global fresh apple producer (45 million tonnes year$^{-1}$) with continued growth of its production capacity (USDA, 2021). Although the effects of aesthetic preference and food shape abnormality are substantial in China (Loebnitz and Grunert, 2015), rigorous studies about the substantial practices of aesthetic preference against food shape abnormality are scant. As one of the most consumed fruit globally, apples can be used as a relevant example in relation to non-conformity with cosmetic standards (Bolos et al., 2019). Taking advantages of a unique dataset from field surveys on a variety of chain stakeholders, the article and the findings critically challenge the ethics and values of excessive grading based on aesthetic characteristics in the current food system and call for an alternative approach that highlights human-agroecology and communication between producers and consumers. Lastly, the survey and data were conducted about 10 years ago and the agri-food chain organization might change in years afterwards. Hence, this research may provide a baseline for future research on food losses of fresh apple and agribusiness transformations in developing countries.

## Conceptual framework: Grading, standards and agri-food organizations

As global agri-food chains are becoming increasingly 'buyer-driven', grades and standards by downstream retailers are vital

in governance. The existence of grades and standards often facilitates searches, contractual and pricing arrangements and results in different configurations of economic organization, which sometimes improve market efficiency and sometimes do not (Benham and Benham, 1975). When the attributes of a product are not easily measured or not verifiable during the transaction, indirect mechanisms such as grades, standards and related certification are relied upon (Giovannucci and Ponte, 2005; Henson and Reardon, 2005). Standardization and homogeneous products deal with uncertainties about outputs resulting from difficulties in controlling deliverables that meet consumer preferences and changing demand (John and Weitz, 1988). Grading and standardization can increase enforceability and credibility (of brand names), thereby enhancing market efficiency (Law, 2003). As the food system is increasingly influenced and even 'created' by public authorities and companies, food governance and its fundamental values are moving away from the producers, especially smallholders in developing countries (Busch, 2000; Fuchs et al., 2011b). The proliferation of private standards is associated with the emergence of supermarket and centralized procurement systems based on dedicated suppliers and contractual arrangements. These forces work against decentralized innovation and favour ex ante partner selection and contracting (Henson and Reardon, 2005).

On the other hand, public institutions at the national and international levels seek a role in re-governing the agri-food system towards sustainability transition. Compared with private standards that are often used to distinguish the product as a strategy for firms to increase their competitive advantage, public authorities generally set minimum quality standards (Deaton, 2004; Fulponi, 2007; Jaffee and Masakure, 2005; Tanner, 2000). In addition to the national frameworks, international agricultural quality standards are developed and released by the United Nations Economic Committee for Europe (UNECE) for a wide range of agricultural products and are voluntarily applied by governments, producers, traders, importers, exporters and organisations. The standards are not legally binding and revised on a regular basis. Importantly, UNECE responded to the FLW discussion with several supplementary publications including a Code of good Practice in order to reduce losses (UNECE, 2020a) and a simple measuring food loss methodology for fresh produce supply chains (UNECE, 2020b). On the other hand, since 1963, the Codex-Alimentarius, international standards, guidelines and codes of practice are seen as recommendations for voluntary application by food supply chain actors but also form the basis for several national legislation.

Current analysis of agricultural standards in agri-food sector appears to be unbalanced and incomplete. The majority of research on agricultural standards focuses on unobservable characteristics, such as safety, nutrition, animal welfare and environmental sustainability (Codron et al., 2005; Giovannucci and Ponte, 2005; Henson and Jaffee, 2008; Rau and van Tongeren, 2010; Sawyer et al., 2008; Swinnen and Vandemoortele, 2008; van der Meer, 2007). Some characteristics can be measured in a cheap way using inexpensive methods, for example fresh fruit is sorted in sizing facilities using simple tools (e.g. ring sizer). Other attributes, such as taste, safety and nutrient content, cannot be measured non-destructively and may not even be visible to the producer and intermediaries; measurement and creditability are often delegated to professional entities (such as certification bodies). However, between these two extremes are characteristics that are valued by prospective consumers and can be measured through commonly shared rules and norms, such as ripeness, colour, fragrance, bruising, intactness and appealing appearance. Differing from nutrient characteristics, these aesthetic characteristics are mostly observed and are difficult to communicate as the rules are neither precise nor codified.

The lack of knowledge about aesthetic standards at the farm gate limits global actions on empowering smallholder farmers in developing countries. Different grade and standard schemes reflect the variable degree of formalism and power embodied in the governing entities, which affect the resulting transaction costs (Menard, 2004). By entrusting regulatory agencies or a third-party entity (such as associations) with certifying standards, the partners create a private 'court' or a joint committee of peers elected among professionals, who are in charge of solving conflicts and distributing the quasi-rents (Hadfield, 2005). In most advanced market democracies, the state delegates the authority to govern admission and practice to one or more self-governing professional organizations. The rationale for professional oversight is rooted in the perceived need to exercise expertise on behalf of clients who presumably do not have sufficient competence or loyalty. Nevertheless, it has frequently been observed that, when the efficiency of a codified rule is in doubt, interpretations of flexible standards and 'norms', such as 'excellent', 'medium' and 'minimum acceptable', are made (Arrunada and Andonova, 2005). The inclusion of multiple grades and standards in our study –that is size, public and private quality standards and non-communicative norms (that characterize, e.g. ripeness through colour, fragrance, intactness, bruising and appealing appearance) – enable a better understanding of the governance of agri-food systems and of the economic benefits that accrue (or not) to smallholder farmers under the different regimes.

## Methodology, survey and data

To study the practices of aesthetic grading and standards that are applied at the farm gate and to compare associated loss of fresh apples by different chain organizations, the research focused on China's major production area, the provinces of Shandong and Shaanxi, where the apple production accounts for 75% of the national profile. The research team studied two major international retailers and their supply chain of fruits throughout 2014 and 2015. The chief procurement manager of fresh produce from each retailer was interviewed at the beginning of the project. The research team asked for a complete list of their suppliers of fresh fruit. Through coordination between the managers and the procurement department, the research team reached all the suppliers on the lists and asked them for the source of their procurement of fresh apples.

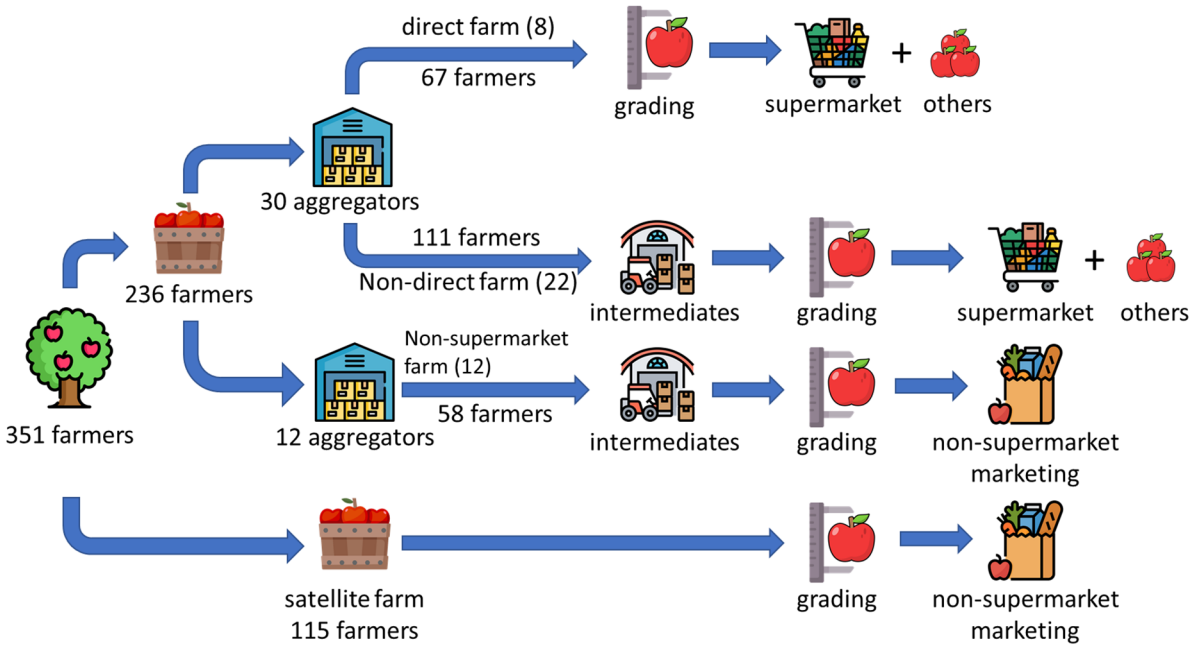


**Figure 1.** Scheme of supply chain organisation assessed in the present study. The numbers refer to the numbers of apple growers displayed in Table 1, those in brackets relate to the numbers of aggregation clusters.

The chain organizations of fresh apples in the studied area are complex and pluralistic. To enhance quality assurance and better control of the timing of their supplies, the supermarkets were in direct contact with some farm communities and local aggregators. In addition to the 'direct farm' scheme, the supermarkets mainly relied on several large agribusiness suppliers with a national outreach and cold storage, transport and logistic facilities. The vendor intermediaries procured the products from local aggregators and farm communities and supplied supermarkets in addition to other marketing outlets (see Figure 1). To explore possible marketing with other supermarkets with fresh apples in the study regions, we selected additional villages where the production of fresh apples was similar to that in the villages identified by the supermarkets and their vendor suppliers. In this way, we identified and gathered data from villages and farm communities that supplied supermarkets other than those belonging to the two large international retailers.

Through face-to-face surveys of vendor companies and community aggregators, we obtained a list of member farmers who supplied the supermarkets either directly or via intermediary companies. During the household survey, we randomly selected six farmers from the list and additional four apple growers in the same villages who were not on the list as controls. To be compared with the farms supplying the intermediary companies, the off-list farms are labelled as 'satellite farms'. To complete our main objective of investigating grading at the farm gate, we conducted a survey on marketing of the apples (e.g. the transaction details, loss, dates, buyer identity, volume, price, grading schemes), on production practices (e.g. apple bagging, labour use) and household and farmer's characteristic (e.g. the farm size, the farmer's age and education). The post-harvest survey lasted for 8 months until farmers completed their sales in the next year. The survey was conducted in the years of 2014 and 2015. It is possible that new agribusiness forms of apple production were emerging afterwards. Therefore, the conducting research provides a baseline for future research to study aesthetic grading at the farm gate in the studied areas.

**Table 1.** Sample description and research design in China, 2014.

| Apple farm | Number of aggregation clusters of fresh apples | Number of apple growers |
|---|---|---|
| Supermarket farm | 30 | 178 |
| Direct farm | 8 | 67 |
| Non-direct farm | 22 | 111 |
| Non-supermarket farm | 12 | 58 |
| Satellite farm | n.a. | 115 |
| Total | 42 | 351 |

n.a.: None applicable.

Finally, we constructed a hierarchical dataset consisting of 351 apple farmers. In these regions, we identified 30 aggregators supplying supermarkets (directly or through vendors). This resulted in a farmer identity of 'supermarket farms' – 67 of which supplied supermarkets directly, 111 farmers who supplied supermarkets through vendor intermediaries. And 58 farmers who were attached to the remaining 12 aggregators and identified of 'non-supermarket farms' did not supply a supermarket at all. In addition to the farmers attached to aggregation clusters, we selected 115 farmers who made their decisions independently from aggregators or vendor intermediaries. This resulted in another group identity of 'non-supermarket farms' totalling 173 (= 115 + 58, see Table 1).

**Table 2.** Grading schemes of fresh apples at farm gate in China, 2014.

| Grading schemes | Total ($N$ = 351) | Supermarket-coordinated farms | | | Non-supermarket farms ($N$ = 173) |
|---|---|---|---|---|---|
| | | Total ($N$ = 178) | Direct farm ($N$ = 67) | Non-direct farm ($N$ = 111) | |
| Apple cropping area (ha) | 0.8 | 0.8 | 0.9 | 0.8 | 0.8 |
| The rate of apple loss by grading (%) | 15.8 | 15.8 | 16.5 | 15.4 | 15.8 |
| Grading by cosmetic characteristics | 17.1 | 17.0 | 17.9 | 16.2 | 17.2 |
| Grading without cosmetic characteristics | 14.9 | 15.0 | 14.8 | 15.0 | 14.9 |
| Marketing volume by grading (%) | | | | | |
| Grading by cosmetic characteristics | 34.7 | 35.2 | 46.5 | 28.3 | 34.2 |
| Grading without cosmetic characteristics | 65.3 | 64.8 | 53.5 | 71.7 | 65.8 |
| Marketing volume by size (%) | | | | | |
| Very large: above 85 mm | 8.2 | 7.1 | 10.2 | 5.1 | 9.3 |
| Large: 80–85 mm | 31.9 | 35.9 | 39.6 | 33.6 | 27.9 |
| Medium: 75–80 mm | 21.9 | 19.8 | 25.3 | 16.5 | 24.0 |
| Small: 70–75 mm | 30.8 | 29.4 | 17.4 | 36.6 | 32.3 |
| Very small: below 70 mm | 7.2 | 7.8 | 7.4 | 8.1 | 6.6 |

Source: Author's survey.

## Empirical analysis and research findings

### *Descriptions*

All fresh apples were graded by size in the field and the grading was simple by using a set of rings with different diameters; the smallest ring was often 60 mm and the largest was 85 mm. Apples were referred to as 'very small' when the diameter is less than 70 mm. 'Small' apples had a diameter of less than 75 mm measured with rings. 'Medium' apples often had a diameter between 75 and 80 mm. 'Large' apples had a diameter of more than 80 mm and 'very large' apples a diameter of more than 85 mm. In general, supermarket chains preferred 'large apples' for raising retailing volume. For example, on average 43% of fresh apples delivered to the supermarket directly or indirectly were graded by targeting a size of more than 80 mm in diameter (rows 9 and 10 in Table 2).

The average volume is 34.7% for fresh apples which was graded in terms of aesthetic characteristics (row 6 Table 2). Although the criteria vary from place to place, grading instructions based on aesthetic characteristics included intactness (i.e. no bruising or worm attacks), ripeness, regular shape, colour and appealing appearance. Although the rules and norms were shared in the rural communities, the measures were subjective (such as appealing appearance). Apples of different aesthetic characteristics are often graded as 'excellent', 'medium' and 'minimum acceptable'. Fresh apples were graded in terms of aesthetic characteristics at the farm gate, and that the values for supermarket (35.2%) and non-supermarket (34.2%) regime is almost the same (row 6 Table 2). Nevertheless, within the supermarket supply chain category, 46.5% of the fresh apples supplied directly to the supermarket were graded according to the aesthetic characteristics mentioned above, while the percentage was much lower for non-direct farms (28.3%). The findings were verified when surveying with the procurement managers of the supermarkets. When procuring directly from farms, supermarkets tend to outsource grading to the aggregators in the villages and vendor intermediaries to avoid additional costs and waste.

Our results indicate, the price paid to farmers was lower for apples only graded by size as when fresh apples were graded by aesthetic characteristics, and this price difference was observed in different chains. To explore the difference in the price paid by chain organizations and grading based on aesthetics characteristics, we broke down the data in Table 2 (lower panel) into the categories shown in Table 3. The breakdown was very helpful. For example, the price difference of apples sizing from 80 to 85 mm between aesthetically graded apples, and those not graded was USD 0.18 $kg^{-1}$ (Table 3) in the study area. Although supermarkets preferred 'large' apples, a price discrimination was applied for fresh apples graded through aesthetic standards; the price difference in supermarkets was USD 0.26 $kg^{-1}$ for apples of 80–85 mm size but only USD 0.13 $kg^{-1}$ for 'small' apples of 70–75 mm. Compared with supermarket coordinated chains, fresh apples procured through non-supermarket chains had a higher percentage of medium size (Table 2). As a result of increase the percentage of 'medium' size apples, a larger price difference was applied accordingly for apples being graded through aesthetic characteristics (Table 3).

Compared with apples grading without cosmetic characteristics, the rate of post-harvest losses of fresh apples on farms caused by the aesthetic grading was astonishingly high. As shown in Table 2, about 17.1% of harvesting volume was considered inappropriate for marketing mostly because of aesthetic standards. Most of the rejected apples were used either for processing or for feeding animals. The figure does not vary much between the different chain organizations.

### *Model specification*

Descriptive analysis showed its limitations when it came to examine the impacts of grading schemes on loss and prices. In

**Table 3.** Price difference of fresh apples (USD kg$^{-1}$) with and without cosmetic characteristics by chain organizations in China, 2014.

| Size (mm) | Total ($N$ = 351) | Supermarket-coordinated farms | | | Non-supermarket farms ($N$ = 173) |
|---|---|---|---|---|---|
| | | Total ($N$ = 178) | Direct farm ($N$ = 67) | Non-direct farm ($N$ = 111) | |
| Very large: above 85 | 0.20 (1.3) | 0.23 (1.2) | 0.24 (1.13) | 0.19 (1.29) | 0.23 (1.38) |
| Large: 80–85 | 0.18 (1.14) | 0.26 (1.07) | 0.26 (1.0) | 0.19 (1.16) | 0.07 (1.23) |
| Medium: 75–80 | 0.25 (1.0) | 0.08 (0.98) | 0.40 (0.97) | 0.04 (1.0) | 0.25 (1.01) |
| Small: 70–75 | 0.14 (0.8) | 0.13 (0.81) | 0.15 (0.7) | 0.07 (0.91) | 0.16 (0.79) |
| Very small: below 70 | 0.05 (0.53) | 0.02 (0.55) | 0.09 (0.47) | −0.02 (0.6) | 0.09 (0.49) |

Source: Author's survey.
Figures in parentheses are absolute price in USD for fresh apples without being graded by cosmetic characteristics. The exchange rate of the yuan against the dollar was 0.1622 in 2014.

addition to the diversity and complication of chain organizations, other transaction-specific factors (such as timing, i.e. sold in the harvest season or off-season) and farm-level factors (such as farm experience, farm size, etc.) need to be accounted for and be controlled. Taking advantage of the cross-sectional data at household level and the panel data at transaction level, we specify two multivariate regression models that seeks to identify the correlation between the impacts of grading schemes on loss and prices, respectively. Our basic modes are:

$$\text{Loss}_i = a_0 + \theta\text{COSMETIC}_i + \delta\text{CHAIN}_i + \rho\text{OTHER}_i + \mu_i \quad (1)$$

$$\text{Price}_{ik} = a_0 + \theta\text{COSMETIC}_{ik} + \beta\text{SIZE}_{ik} + \delta\ \text{CHAIN}_i + \rho\text{OTHER}_i + \mu_{ik} \quad (2)$$

where $\text{Loss}_i$ is the rate of post-harvest losses at the farm gate for apple grower $i$. $\text{Price}_{ik}$ is the outcome variable that measures the price of fresh apples that farm $i$ in the $k$th transaction in the marketing season.

The key variables of interest, $\text{SIZE}_{ik}$ and $\text{COSMETIC}_{ik}$. $\text{SIZE}_{ik}$, include a set of binary variables indicating the precise size of fresh apples in the $k$th transaction, that is 'very large' more than 85 mm in diameter, 'large' 80–85 mm, 'medium' 70–80 mm, 'small' 70–75 mm and 'very small' under 70 mm (baseline group). In equation (1), $\text{COSMETIC}_i$ is a dummy variable, which a value of 1 when the fresh apples is graded by a combination of size and aesthetic characteristics one time during all transactions and 0 otherwise. In equation (2), $\text{COSMETIC}_{ik}$ is a dummy variable with a value 1 or 0 that indicate fresh apples that are graded by a combination of size and aesthetic characteristics in the $k$th transaction. We controlled the chain specific characteristics in $\text{CHAIN}_i$, such as the organization of the chain (i.e. direct sale between the farm and the supermarket, indirect supplies from the farm to the supermarket and farms supplying outlets other than supermarkets) and the certifications indicating a public or and private production standard. Lastly, we controlled several households and individual characteristics in $\text{OTHER}_i$. A summary of the variables is presented in the Appendices 1 and 2.

Table 4 presents the estimated results using ordinary least squares (OLS) approach. Table 5 presents the estimated results both using OLS and fixed effects approaches. According to the results of the descriptive analysis, the relations between grading based on aesthetic appearance and the organization of the chain appear to be complex. To test this hypothesis and to strengthen the robustness of our estimations, we included the two parts of variables stepwise into the estimations (columns (1) and (2) in Table 5) and also estimated them fully (column (3), Table 5).

**Table 4.** Multivariate analysis of the rate of fresh apples loss in China, 2014.

| | |
|---|---|
| Cosmetic variable | |
| Grading by cosmetic characteristics (Yes = 1; No = 0) | 4.50*** (2.87) |
| Chain variables | |
| Non-supermarket farmers (Yes = 1; No = 0) | 0.05 (0.03) |
| Control variables (other variables) | |
| Age of farmer (years) | 0.10 (1.18) |
| Farming experience in apple production (years) | −0.09 (1.06) |
| Apple cropping area (ha) | −0.24 (0.96) |
| Public standards (Yes = 1; No = 0) | 1.64 (1.15) |
| Private standards (Yes = 1; No = 0) | −1.24 (0.59) |
| Shandong province (Yes = 1; No = 0) | 5.43*** (3.48) |
| Constant | 2.85 (0.49) |
| $F$ value | 2.43 |
| Prob > $F$ | 0.01 |
| $R^2$ | 0.05 |

Absolute values of $t$-ratio in parentheses. The sample size used in the regression is 351.
*** Indicates statistically significant at the 1% level.

## Results of model

On-farm post-harvest losses of fresh apples were associated with the type of chain organization. As shown in Table 4, the variable of cosmetic characteristics is significantly positive, showing that, after controlling other factors, fresh apples grading by aesthetic characteristics had a higher level of on-farm losses after harvest. In addition, regional variation was notable and the rate

**Table 5.** Multivariate analysis of farm gate prices of fresh apples in China, 2014.

| Variables | OLS | | | FE |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Cosmetic variable | | | | |
| Grading by cosmetic characteristics (Yes = 1; No = 0) | −0.06*** (3.01) | | −0.06*** (2.74) | −0.04 (1.15) |
| Size variable | | | | |
| Grading by size measured in millimetres in diameter (Yes = 1; No = 0) | | | | |
| Very large: above 85 | 0.93*** (17.83) | 0.91*** (17.39) | 0.93*** (17.90) | 0.85*** (19.36) |
| Large: 80–85 | 0.70*** (19.38) | 0.69*** (18.69) | 0.70*** (19.44) | 0.66*** (19.82) |
| Medium: 75–80 | 0.50*** (16.04) | 0.49*** (15.56) | 0.50*** (16.16) | 0.48*** (15.10) |
| Small: 70–75 | 0.32*** (11.73) | 0.31*** (11.16) | 0.32*** (11.70) | 0.29*** (10.43) |
| Chain variables | | | | |
| Direct farm with supermarkets (Yes = 1; No = 0) | | −0.10*** (3.54) | −0.10*** (3.43) | |
| Non-direct farm with supermarkets (Yes = 1; No = 0) | | −0.01 (0.40) | −0.01 (0.61) | |
| Control variables (other variables) | | | | |
| Transactional volume (kg) | 0.01*** (3.52) | 0.01*** (3.67) | 0.01*** (3.53) | 0.02*** (8.59) |
| On-season sales (Yes = 1; No = 0) | 0.22*** (10.64) | 0.22*** (10.79) | 0.22*** (10.48) | 0.30*** (8.73) |
| Age of farmer (years) | −0.00 (0.40) | −0.00 (0.06) | −0.00 (0.59) | |
| Farming experience in apple production (years) | 0.00 (1.63) | 0.00 (1.03) | 0.00 (1.37) | |
| Apple cropping area (ha) | −0.04*** (3.60) | −0.04*** (3.58) | −0.04*** (3.55) | |
| Public standards (Yes = 1; No = 0) | −0.01 (0.51) | 0.03 (1.51) | 0.03 (1.41) | |
| Private standards (Yes = 1; No = 0) | −0.02 (0.81) | −0.00 (0.05) | 0.00 (0.11) | |
| Shandong province (Yes = 1; No = 0) | 0.07*** (2.78) | 0.09*** (3.45) | 0.07*** (2.64) | |
| Constant | 0.30*** (3.78) | 0.27*** (3.48) | 0.33*** (4.08) | 0.33*** (9.38) |
| *F* value | 69.92 | 64.70 | 68.65 | 128.11 |
| Prob > *F* | 0.00 | 0.00 | 0.00 | 0.00 |
| $R^2$ | 0.41 | 0.41 | 0.42 | 0.49 |

Absolute values of *t*-ratio in parentheses. The sample size used in the regression is 1308.
FE: fixed effects; OLS: ordinary least squares.
*** Indicates statistically significant at the 1% level.

of apple loss was higher in Shandong Province when compared with Shaanxi.

Aesthetic grading was negatively associated with the price at the farm gate. As shown in Table 5, after controlling other transactional, organizational and individual factors, the coefficients of grading based on appearance are negative, showing that grading based on appearance reduced the farm gate price. The results of the key variables are consistent across different model specifications, indicating a weak association between the grading scheme based on appearance and on the organization of the chain in determining prices, meaning grading by aesthetic characteristics (such as ripeness, colour, fragrance, bruising, intactness and appealing appearance) had no economic benefits for individual farmers.

The direct supply of apples from farms to supermarkets had a downward effect on the farm gate price. Table 5 shows that the coefficient of the variable 'Direct farm with supermarkets' is negative and significant. The results are robust and indicate a negative effect on income by the supermarket-driven chain, ceteris paribus. These findings coincide with the results of some other studies. For example, Michelson et al. (2012) found that prices paid by Walmart to farmers were significantly lower than the prices paid in the traditional market in Nicaragua. Although the contracts with large retailers helped reduce price volatility, the cost of the contractual insurance was high for smallholder farmers in developing countries.

We found no price premium related to production standards and certifications in China's fresh apple chain. The coefficients of the variables of public and private standards were insignificant, and this shows that apple growers in China did not economically benefit from complying with any production standards. This finding is consistent with one recent study on China's transforming agri-food chain, and the study showed that agricultural standards and certifications were by and large a marketing strategy that failed to improve knowledge acquisition (Ding et al., 2019). In other regions of the world, the economic benefits associated with certification of agricultural products are not conclusive, for example for green beans in Senegal (Maertens and Swinnen, 2009) and vegetables in Kenya (Minten et al., 2009; Rao and Qaim, 2011). Together with the evidence from China, it shows that the promotion of agricultural standards and grading and transforming agri-food chain play a limited role in benefiting smallholder farmers.

**Table 6.** Bagging cost in apple production in China, 2014.

| Bagging cost | Total | Supermarket-coordinated farms | Non-supermarket farms |
|---|---|---|---|
| Bagging practices in apple production (%) | 98.8 | 98.2 | 99.3 |
| Percentage of bagging expense from total cost | 19.9 | 19.8 | 20.0 |
| Total cost related to bagging (USD $ha^{-1}$) | 3328.2 | 3410.6 | 3239.4 |
| Materials (%) | 37 | 37 | 37 |
| Labour (%) | 63 | 63 | 63 |

*Source*: Author's survey.

## Discussions: Aesthetic grading, food losses and where next

In an anecdotal interview decades ago, several growers of Red Delicious apples in Washington State (USA) reported losses due to excessive grading (Egan, 2000). As one farmer put it in an interview, 'For almost 50 years, we've been cramming a red apple with ever thicker skin down the consumer's throat, sometimes mushy, sometimes very good if done right, but a product that was bred for colour and size and not for taste'. What is the rationale behind aesthetical standards and grading, if it harms growers and the environment and becomes costly for consumers?

The myth of aesthetic standards and the application in agri-food sectors has not been researched sufficiently. In Germany, apple producers separate out undersized (smaller than 60 mm) or oversized (larger than 90 mm) apples during harvest in order to save storage capacity for the marketable produce only (Peter et al., 2013). De Hooge et al. (2018) interviewed German and Dutch supply chain actors who indicated only low motivation to introduce non-conform produce for sale in supermarkets due to assumed basic market mechanism and pricing strategies. Non-conform products being sold at a lower price would be at the expense of high-quality conform produce as well. However, half of the interviewed producers and retailers agreed that there are potential consumer markets for such suboptimal produce such as weekly local markets and they would not have any problem to handle and market those products. In the present study, there was an accurate quantification of that financial disadvantage for the farmers (see Table 5), which is in line with the respondents from Roels and van Gijseghem (2017) reported the perception that the price they receive is insufficient. From a total of 20 apple growers, 15% reported a loss between 25% and 50% and the final 20% of growers mentioned a sale loss rate of over 40%. This was also one reason why 43% of the Flemish respondents recommended decreasing cosmetic requirements. So, where does the requirement come from historically? More research should be done on this topic or the issue should be reflected against present developments related to food system transformation.

Aesthetic grading matters for both economics and environment. A case study from Flanders/Belgium surveyed the most likely options for products which do not fulfil the standards (multiple answers possible): 58% of the down-graded produce are marketed at lower price for human consumption, about 35% are not harvested, 25% are used for land application, 14% are sold to industrial processing, nearly 12% are directly sold to consumers at farm gate, 11% used as animal feed and 11% end up in composting facilities (Roels and van Gijseghem, 2017). It has to be mentioned that those shares vary by product and also depends on current market conditions. In Germany, apples, which are not marketed towards the fresh market, are usually sold to food processing industry for the juice or apple puree production, marketed directly from farm to consumer (e.g. weekly markets, farm-gate sale, delivery services) or are used for animal feed (Peter et al., 2013). But those alternative marketing options are only feasible if the price allows the additional costs for handling – thus, varying economic framework influences the final destiny of the products and the corresponding environmental impact by case.

Although aesthetic grading is popular in the agri-food sector of fresh vegetables and fruits in China, the on-farm practices are not well known outside the industry. To give fresh apples a 'good look', Chinese farmers use little paper bags over developing fruits so that the fruits are protected from insects, diseases, spraying of pesticides and to prevent disfigurement. Each of the apples is bagged shortly after the blossoms drop, and the bags are taken off about 2 weeks before harvest so the fruits rapidly turn red in the sunshine, sometime with the aid of reflective films that enhance the photosynthetic capacity of the leaves and improve fruit quality. Imagine that a grower has to hire labourers to bag at least twice during the growing season, the labour costs are not negligible. According to our survey, the average cost of hiring labour for bagging is USD 30 per day in the busy season. The total expense of bagging costs, including hiring labour and equipment, was USD 3328 $ha^{-1}$, accounting for 20% of the total cost of producing fresh apples (see Table 6).

Aesthetic standards and grading also inspire debates on values and ethics within the agri-food system. Farm practices in China's apple production are mainly conducted by skilled women of advanced ages. However, reports of injuries and heavy tolls (damage caused by stabbing and falls) linked to the bagging of fresh apples for meeting with aesthetic standards are not rare on Chinese social media. The findings of this study should lead to further reflection on the ethics and value of an overall food system governed by aesthetic standards. Many studies support agricultural standards and food attributes to promote environmental sustainability, animal welfare and social inclusion (Asfaw et al., 2010; Carlsson et al., 2007; Giovannucci and Ponte, 2005;

Hammoudi et al., 2009). Research into the values and ethics of different aspects of our food system is important, as it restructures the boundary of agri-food system towards an extended nexus of human-agroecology. However, although grading based on aesthetic characteristics is widely used for many agricultural commodities and for the market, its rationale has not yet been critically discussed. If the food system is to truly embrace sustainability and human beings as the overall context, then it is important to include ethical considerations (Bawden, 2012). Such ethical questions lead to thinking about 'how it should be', and not only 'how it is today'. For the overall food regime, why do products have to 'look perfect' if this involves high costs to the economy, environment and society? To evaluate the legitimacy of food governance, the criteria of participation and communication need to be considered (Fuchs et al., 2011a, 2011b; Porter and Ronit, 2010). Food system transformation is also a communicative process that reflects societal values.

Keeping in mind increasing global and regional resource shortage, the question is how costly the external environmental effects of using edible apples for non-food purposes are on our resource system. The quantitative assessment related to the environmental effect of downgraded apples was far outside the aim of the present study, also literature data are lacking. For highlighting the importance of the issue, we cite the findings of Goossens et al. (2019) who calculated the apple supply chain for Belgium for regional apples and those imported from New Zealand from primary production until consumer. The authors conclude that for seven out of nine assessed environmental indicators, between 10% and 30% of the impact refers to apples that entered the food chain but were, in the end, not consumed. The highest share of impact was related to the disposal option which indicates that also small improvements to add value to downgraded apples might have a significant impact on lowering environmental effects. Additional to produce disposal losses, the widespread use of bags and film for bagging practices in China's apple production observed during our study, may also have negative environmental impacts. As these potential impacts have not yet been rigorously studied and evaluated, we recommend further research be done in this area.

The findings of this study openly challenge the rationale behind excessive grading based on aesthetic characteristics and the socio-psychological aspects of consumptionism. Firm fresh red apples may appeal to the eye of shoppers in a hurry. But are these aesthetic characteristics truly recognized and valued by consumers? In an experimental study, researchers found that diagnoses based on visual inspection were poorly correlating with how the quality was judged when the product was being consumed; meaning the apples they judged to be 'perfect' at time of shopping were in fact not their favourite at time of consumption (Ligon, 2002). Most studies on consumer acceptance of so-called suboptimal products focus on items with flaws such as products with unusual shape, small skin damages or an expired best-before date. For example, De Hooge et al. (2017) found out that although 25% of their Northern European respondents are willing to buy a curved cucumber, only 2.6% of the people would take an apple with a spot in the supermarket. So, the first question is which of the applied aesthetic characteristics are visually recognized by consumers and which are not – meaning, if products which do not comply with specific cosmetic standards are perceived as 'suboptimal' by consumers. Secondly, the degree of tolerance of suboptimal characteristics depend on product associations (e.g. safe to eat, perceived taste) and the intended use (cooking, consume as it is) among others. In case of De Hooge et al. (2017), deviation in terms of colour (an apple with a spot) was accepted with strong limitations only while an unconventional shape was not a barrier. In line with this, Normann et al. (2019) found that consumers responded with decreased willingness to choose an apple if at least two out of three suboptimal properties (colour, shape, damage) were visible. Jaeger et al. (2018) confirmed with their findings related to consumers in Uruguay that the external defects on apples (cut, crushed or bruised) led to a low willingness to choose. We conclude that there should be more psychological and behavioural research on attributes relevant for different food items and aesthetic characteristics which determine consumers' purchase decisions.

In contrast with the lagging research on food waste associated with aesthetic standards, social innovations are rising from the mainstream business and the civil society. In practice, there are already examples of the introduction of suboptimal food as separate brands in supermarkets. One international forerunner was the Swiss company Coop who introduced the own brand 'Ünique' related to misshaped products in summer 2013. In 2014, 180 tonnes of carrots and 36 tonnes of pears were sold. Due to the positive response of the consumers, the assortment was widened towards a variety of fruits and vegetables (Coop, 2015). In 2020, a total of 1450 tonnes of fruit and vegetables were marketed under the brand. In Austria, supermarkets belonging to the REWE group started to launch the brand 'Wunderlinge' ('whimsicals') in late 2013. The assortment started with apples, carrots and potatoes but was expanded to other products such as peaches and onions in 2016. The offered variety depends on season, the packaging size is larger than with normal products (1.5–2.5 kg) and the price level is less than conventional. In 2019, 8275 tonnes of 'Wunderlinge' were sold. Devin and Richards (2018) assessed the context of Australian retailers' corporate social responsibility (CSR) activities and different food waste issues. They conclude that the interviewed stakeholders implemented mainly in-store measures to reduce food waste but did not value the impact of their strict cosmetic standards of fruits and vegetables which could have much more impact. Motivation for food waste prevention measures were reduced costs for waste management and thus, waste which occurs on other premises is not in the focus of supermarkets. Devin and Richards (2018) argued that due to the Australian food retail duopoly, stronger governmental regulation and intervention are recommended to push food waste prevention throughout the supply chain. Penny, another retailer from Germany and also belonging to the REWE group, started to market 13 organic fruit and vegetables products by introducing their

own brand 'Bio-Helden' ('organic heroes') in 2016 within all its 2200 outlets. The unique approach is that the non-conform items are not graded and packed separately but mixed with conform products according to their natural occurrence. Thus, there is no additional effort for the farmers during sorting and packing and there is no price discount at sale. Until February 2022, the assortment was enlarged to a total of 37 different products. On average, the sales amount increased by 6% which was topped by an increase of 27% in 2021. This was significantly higher than the development of the overall sales of FFV at Penny.

## Conclusions

The study has a unique value for the global debates and actions against FLW as it quantifies on-farm post-harvest losses of fresh apples by different agri-food chain organization in China with respect to mass and economic value. About 18.6% of production on average were considered as food losses, mainly caused by aesthetic grading (i.e. ripeness, colour, fragrance, bruising, intactness and appealing appearance). It was found that 35% of the volume in China's major production areas of fresh apples were graded by these aesthetic characteristics. The grading scheme that favours 'perfect' appearance, however, did not yield economic benefits for smallholders. Lastly, direct procurement by supermarkets had a depressive effect on the price of fresh apples at the farm gate. To our knowledge, the key findings of this study have not ever been made in previous studies.

The reduction of apple losses may contribute not only to the Sustainability Development Goals (SDG) 12.3 (reduction of food loss in upstream supply chain) but also to other SDGs. Due to the high content of valuable nutrients and vitamins, an increase of apple intake could support preventive health measures on broad population basis. Marketing of a higher share of the actual production could also have a positive impact on food access for disadvantaged population groups. Further high-value processing of downgraded apples could also secure local work places, income and rural development in the respective production areas in comparison of present use as animal feed or waste management.

In order to achieve highest economic value for farmers and other stakeholders (such as processors), there is need for sourcing cooperation with necessary entrepreneurial and technological innovations, such as the already existing cases such as from Europe. More and more retailers include their supply chain activities into their CSR activities which also impacts on-farm food losses. Possible actions include relaxing individual cosmetic specifications in general and in addition to introduce 'imperfect produce' brands. As studied in this article, there are different perceptions of specific visual aspects by consumers influencing the willingness to pay. Thus, the type of attribute (colour, size, damage) should be carefully distinguished and addressed by cosmetic standards in order to meet real consumer expectations in a first step. Those activities could lead to an increasing understanding of the consumer about value of food and natural appearance of food. Further adjustments of cosmetic standards could then follow the already achieved changed consumer attitudes. To overcome the hen and egg problem, those activities should be well designed for upscaled implementation and include education of consumers as well as learning from best cases within production, marketing and retailing. It is important that actions towards a shift in social norms related to aesthetic standards and expectations are implemented by different stakeholder groups in parallel, meaning not only on retail level but also on level of civil society. This could be enhanced by policy intervention such as awareness campaigns to support acceptance and requests of so-called ugly fruits and vegetables.

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**Appendix 1.** Simple means and standard deviations of all variables used in regression 1.

| Variables | *N* | Mean | Standard deviation |
|---|---|---|---|
| Independent variable: The rate of loss (%) | 351 | 15.80 | 12.12 |
| Cosmetic variable : Grading by cosmetic characteristics (Yes = 1; No = 0) | 351 | 0.40 | 0.49 |
| Chain variables: Non-supermarket farmers (Yes = 1; No = 0) | 351 | 0.49 | 0.50 |
| Control variables (other variables) | | | |
| Age of farmer (years) | 351 | 51.20 | 8.80 |
| Farming experience in apple production (years) | 351 | 20.74 | 7.64 |
| Apple cropping area (ha) | 351 | 0.79 | 1.51 |
| Public standards (Yes = 1; No = 0) | 351 | 0.42 | 0.49 |
| Private standards (Yes = 1; No = 0) | 351 | 0.11 | 0.31 |
| Shandong province (Yes = 1; No = 0) | 351 | 1.40 | 0.49 |

**Appendix 2.** Simple means and standard deviations of all variables used in regression 2.

| Variables | *N* | Mean | Standard deviation |
|---|---|---|---|
| Independent variable : Prices of fresh apples (USD $kg^{-1}$) | 1308 | 1.00 | 0.43 |
| Cosmetic variable: Grading by cosmetic characteristics (Yes = 1; No = 0) | 1308 | 0.47 | 0.50 |
| Size variable | | | |
| Grading by size measured in millimetres in diameter (very large: above 85; Yes = 1; No = 0) | 1308 | 0.08 | 0.28 |
| Grading by size measured in millimetres in diameter (large: 80–85; Yes = 1; No = 0) | 1308 | 0.27 | 0.44 |
| Grading by size measured in millimetres in diameter (medium: 75–80; Yes = 1; No = 0) | 1308 | 0.24 | 0.43 |
| Grading by size measured in millimetres in diameter (small: 70–75; Yes = 1; No = 0) | 1308 | 0.26 | 0.44 |
| Grading by size measured in millimetres in diameter (very small: under 70; Yes = 1; No = 0) | 1308 | 0.26 | 0.44 |
| Chain variables | | | |
| Direct farm with supermarkets (Yes = 1; No = 0) | 1308 | 0.23 | 0.42 |
| Non-direct farm with supermarkets (Yes = 1; No = 0) | 1308 | 0.30 | 0.46 |
| Control variables (other variables) | | | |
| Transactional volume (kg) | 1308 | 3.89 | 6.50 |
| On-season sales (Yes = 1; No = 0) | 1308 | 0.61 | 0.49 |
| Age of farmer (years) | 1308 | 51.42 | 8.50 |
| Farming experience in apple production (years) | 1308 | 20.93 | 7.39 |
| Apple cropping area (ha) | 1308 | 0.75 | 1.40 |
| Public standards (Yes = 1; No = 0) | 1308 | 0.44 | 0.50 |
| Private standards (Yes = 1; No = 0) | 1308 | 0.11 | 0.32 |
| Shandong province (Yes = 1; No = 0) | 1308 | 1.27 | 0.44 |