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Strategies to reduce food waste – A case study in India avoiding bruises on apples by optimising orchard management

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Abstract
Mechanical damage such as bruises, which can result in considerable wastage and decline in fruit quality, is a major man-made problem of the apple (*Malus domestica* Borkh.) industry. The extent of the mechanical damage on the fruit depends on preharvest, harvest, and postharvest management. Bruises are often caused preharvest and only become visible postharvest. Improper (rough) handling from harvest to retail can cause bruises on the fruit. In India, the fifth-largest apple producer in the world with more than 2 mil t per year, farmers and the apple industry are in a continuous process of reducing losses caused by mechanical damage. This contribution explains the formation and development of bruises, followed by opportunities to reduce or avoid bruises, with particular regard to the situation in India. Preharvest management on the farm includes factors such as crop load management as well as water and nutrient availability. Harvest management includes factors maturity stage, harvest time during the day, harvest method, soft picking bags, packing and transport of the apple bins out of the orchard.

Keywords: Apple, bruises, farm management, fruit firmness, harvest; picking basket, ripeness

Introduction
As part of the continual work at the University of Bonn to reduce food waste, particularly in apple production systems (Blanke, 2015), the apple cultivation in Northern India (Golombek and Blanke, 2020 and 2022) was investigated. Mechanical damage such as bruises, which can result in considerable wastage and decline in fruit quality, is a major man-made problem of the apple (*Malus domestica* Borkh.) industry. The extent of the mechanical damage on the fruit depends on preharvest, harvest, and postharvest management. Bruises are often caused preharvest and only become visible postharvest and often relate to rough handling.
The demand for high quality apples is increasing, especially in upper income segments of the population, who are willing to pay a high price; this demand exceeds domestic supply (Golombek and Blanke, 2020). The import of foreign high quality apples with a good reputation, amounts to only 8 % - 14 % (since 2014) of the Indian apple consumption of 2-3 mil t /year (Golombek and Blanke, 2020). Apples with slight damages are accepted by lower income groups because of the lower fruit price. To meet the demand for high quality fruit and thereby increase the income of Indian apple farmers and stakeholders of the supply chain, a further rise in fruit quality is desirable, a quality, which also allows storage and profitable supply long after harvest season. The objective of this contribution is to explain the causes of bruise formation and to present opportunities to reduce or avoid bruises, with particular regard to India, in order to support farmers and the trade and reduce food waste.

Material and Methods

On her regular visits to India, the first author studied the situation on site, including visits to orchards and horticultural departments as well as farmer interviews in Northern India. Her findings are supported by scientific studies and literature reports on the topic.

Results and Discussion

Causes of bruising - Impact of mechanical damage and infection risks

By their nature, apples are vulnerable to mechanical damage especially during harvest and post-harvest management. Mechanical damages can be bruises, cuts, puncture, split and abrasion (Opara and Pathare, 2014); bruises result in damaged epidermal and hypodermal tissue without rupture of the skin (Fig. 1) (Opara and Pathare, 2014). Indian consumers judge fruit quality predominantly on size and appearance; minor visible damages result in price and quality downgrading and reduce the financial returns. Significant losses may occur by mechanical damage and resulting spoilage, so that any reduction of only few percent would result in a larger amount of better fruit in the market and improve the economic gain along the whole value chain. Mechanical damages may induce physiological disorders, which can lead to off-flavour, loss of nutritional value, decay and spoilage (Opara and Pathare, 2014), as well as bacterial and fungal infection, which can play a major role in the wastage of apples (Kumari et al., 2018).

Fig. 1a-c: a) Bruises on a 'Granny Smith' apple (left); b) compression of apples against each other or the hard plastic with the largest compression force at the bottom of the pannier, and c) *transport of apple boxes out of the orchard by a porter (right)*

Bruises can be caused by excessive impact, compression and vibration forces. Impact forces result from dropping an apple onto a solid surface (starting from 5-10 cm) or against each other (Opara and Pathare, 2014). Apples are exposed to compression forces a) by the fingers of the picker in the orchard, b) when the size of the apples exceeds the pocket size of the tray, c) excessive fruit stacking (Fig. 1b), d) collapse of the cardboard boxes, or e) an operator forcing cartons into a tight spot (Fadiji et al., 2017; Opara and Fadiji, 2018).

The long-winded transport of the filled plastic boxes on rough terrain out of the orchard (Fig. 1c) can be another potential source for bruises. In hilly orchards, as it is often the case in the apple growing regions of India, apple boxes are carried out of the orchard on the back of porters (Fig. 1c). Shaking and swinging of the boxes or panniers should be avoided if possible, because it might cause a impact forces leading to bruises (Van Zeebroeck et al., 2007). The boxes should be set down with care to minimize further compression damage of the fruit, which can be overcome by training the porters.

Delay in bruise visibility – differences between apple varieties

Bruises on apples do not become instantly visible (Fig. 1) until several hours after the impact; the damaged tissues soften, become indented, brownish or dry (Zhang and Li, 2018). Anyhow, bruises are more visible on green (e.g. Granny Smith; Fig. 1a) or yellow (e.g. Golden Delicious) apples, as the red (e.g. in Red Delicious, Gala) fruit colour often masks bruises (Golombek and Blanke, 2022).

Effect of crop load on the apple tree, water availability and calcium on bruise susceptibility

Crop load on the tree, water and calcium availability affect fruit firmness and are manipulable by flower thinning and pruning to achieve the optimum fruit load for fruit firmness (Solomakhin and Blanke, 2010); both excessive and minute crop load affect fruit firmness and size of the apples. Opara (2007) found a higher bruise susceptibility and lower fruit size when the crop load of 'Gala' was increased under well-watered conditions. Under water deficit, increasing crop load of 'Gala' had no effect on bruise susceptibility, but decreased fruit size. Opara (2007) reported that water deficit decreased bruise susceptibility and fruit size only under high crop load; apple cultivars 'Fuji' and 'Gala' responded to deficit irrigation with firmer and smaller fruit.
Calcium stabilizes cell walls by cross-linking adjacent pectins; in the majority of soils of the Indian apple growing regions of Himachal Pradesh and Kashmir, the content of the available calcium is sufficient.

Conclusions and Outlook

In this contribution, options to reduce bruises on apples are described along all orchard processes with particular regard to the situation in India. Impact, compression and vibration forces cause mechanical damages. Fruit firmness plays an important role in bruise susceptibility. Orchard management can reduce the bruise susceptibility by increasing the fruit firmness with the measures: obtaining an optimal crop load and K/Ca fruit ratio without nitrogen oversupply. Proper harvest management can diminish bruise susceptibility by choosing the optimum harvest date (OHD) according to final destination, possibly a later harvest time during the day when fruit dehydration started and by appropriate harvest methods. Gentle picking, preventing bumps of the harvest bag against the tree, placing apples gently into padded harvest devices and moderate stacking height (Fig. 1b, 2) are suitable measures to reduce impact und compression damages. During transport of the apple boxes out of the orchard, shaking, swinging, and rough handling should be avoided. Adult education would be beneficial for everyone involved in orchard management measures important for the development of bruises.

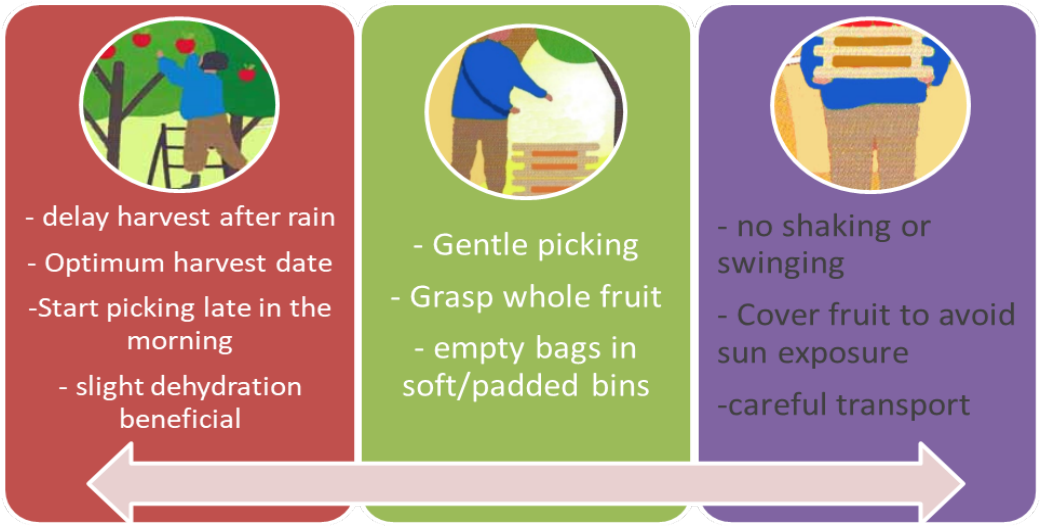

Fig 2. Schematic overview over measures to reduce bruises in apple (Golombek & Blanke, 2022)

A decline of mechanical damage would meet the increasing demand for more high quality apples and improve the income of Indian apple farmers and stakeholders along the whole supply chain and reduce food waste. A quality, which enables storage and profitable supply long after harvest is desirable and would also allow a better competition with foreign imported apples.

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