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Consumer acceptance of disease tolerant apple cultivars

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Abstract: The current study was designed to compare the consumer acceptance of the three *Rvi6* scab-resistant apple cultivars 'Rustica', 'Ariane' and 'Ladina' with the two standard disease-susceptible cultivars 'Braeburn' and 'Mariella'. A consumer test with 189 participants, using written questionnaires, was carried out alongside a sensory descriptive analysis with a trained panel. For appearance acceptance 'Ariane' reached the highest score. Three distinct groups of consumers with different visual preferences were found using hierarchical cluster analysis. In terms of eating quality 'Mariella' was liked the most. Yet again, three groups were found, with specific preferences regarding textural and taste properties. Participants also responded to questions concerning apple consumption and demographics. Significant effects of these parameters on cultivar likings were found. The study showed that there are scab resistant apples which are well accepted and therefore could be equal or superior alternatives to disease susceptible cultivars from a consumer's point of view.

Keywords: apple scab; fire blight; sensory analysis; consumer segmentation

Apple scab (*Venturia inaequalis*) is considered as the most harmful disease in many apple growing areas worldwide. Therefore, many breeding programs are heading for high fruit quality combined with durable resistance towards apple scab, often combined with resistance to the fungal disease powdery mildew (*Podosphaera leucotricha*) and the bacterial disease fire blight (*Erwinia amylovora*) (Peil et al. 2011; Kellerhals 2017).

While Konopacka et al. (2006) found that the scab resistant cultivars 'Rajka', 'Topaz' and 'Rubinola' were assessed lower in eating quality than the standard ones 'Melrose', 'Spartan' and 'Lodel', significant progress in development of disease resistant apple cultivars was achieved in recent years. To be successful from a market perspective, a disease resistant cultivar needs to have equal or higher consumer acceptance for eating quality and appearance than standard cultivars. Buying decisions of consumers in regard to apples have been shown to depend to a large extent by these two factors (Decurtins et al. 2011).

Three cultivars with scab and/or fire blight tolerance were selected for this study. 'Ariane', originating from the INRA breeding program in France and 'Ladina' and 'Rustica' from the Agroscope breeding program at Wädenswil, Switzerland. They all carry the *Rvi6* (Vf) scab resistance. Additionally, 'Ariane' and 'Ladina' are tolerant to fire blight (Laurens et al. 2005; Baumgartner et al. 2012). 'Mariella' carries no specific disease resistance but shows outstanding storage performance. 'Braeburn' was used as a benchmark since it is one of the most common cultivars in the Swiss market and has sensory properties similar to three of the other four tested cultivars – namely high firmness and acidity.

The present study consists of two separate parts, a consumer test and a sensory descriptive analysis with

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a trained panel. The aim of the consumer test was to obtain global hedonic liking-scores for different cultivars from a sample of the German speaking Swiss population across sex and the most relevant age categories. The aim of the sensory analysis was to acquire an analytical sensory description for the tested apple samples. By combining the results of both parts, we aimed for a deeper understanding of consumer segments and their individual expectations in regard to apple consumption.

MATERIAL AND METHODS

Material. The following apple cultivars were selected: 'Ariane', 'Braeburn' (Maririred), 'Ladina', 'Mariella' and 'Rustica'. Date of harvest, origin and analytical results are listed in Table 1. All fruits were stored under controlled atmosphere conditions (O_2 = 1.5 %, CO_2 = 1.5 %) at 1°C and were retrieved from storage on March 3, 2015.

Samples for the sensory descriptive analysis were selected using near infrared spectroscopy (NIRS). The refractometric index (RI) of 40 randomly selected fruits of each cultivar was predicted using NIRS in order to select fruits as homogenous as possible. For each cultivar, five fruits with RI prediction closest to the median value were selected and used for tasting (data not shown).

Analytical data for weight, refractometric index (RI), firmness (penetrometer with a cutting plunger) and acidity were obtained using the analytical robot Pimprenelle (GIRAUD, Cavaillon, France) on April 1, 2015. All measurements were performed with single fruits except for acidity which was analyzed in two batches of ten fruits by titrating with 0.1 M NaOH to an endpoint of pH = 8.1.

Sensory analysis. A sensory descriptive analysis was performed by 12 panelists in separate fully closed booths. Panelists were trained in 5 sessions of 30 minutes with reference samples to achieve consensus for each attribute. All samples were evaluated in a sequential monadic fashion using a completely randomized block design and labelled with random three-digit codes. A line-marking scale of 15 cm with labelled end-points was used for each attribute. No references for scale points were provided. Evaluations were carried out in duplicate with one week between sessions on March 24 and 31, 2015. Panelists received four slices of each cultivar on a white plastic dish prepared using an apple slicer with ten subdivisions. Results were analyzed with Grubbs statistical test (data not shown) and outliers removed accordingly.

Consumer test. A consumer test with written questionnaires in five versions according to a Williams design to balance position effects was performed on March 27 and 28, 2015 in a retail store in Wädenswil (Switzerland), a city with around 21,000 citizens in the urban agglomeration of Zurich. A total of N = 189 (female – 118, male – 71) consumers was selected using convenience sampling. The age distribution was as follows: < 20 a = 36, 20–29 a = 20, 30–39 a = 17, 40–49 a = 24, 50–59 a = 42, ≥ 60 a = 50. The number of consumers for both separate days were $n_{03\text{-}27\text{-}15}$ = 95 and $n_{03\text{-}28\text{-}15}$ = 94, respectively. 107 consumers are regarded as heavy product users, since they stated that they eat apples each day. 62 consumers eat apples 1–2 times per week, eleven consumers 2–3 times per month and eight consumers less frequent.

The different variables, questions and the scales used in the questionnaire are listed in Table 2. Separate coding for appearance and eating quality was used and fruits for each category were presented on separate trays. For judging appearance (9-point likert scale), three apples per cultivar were presented on white Styrofoam dishes. Consumers were allowed to touch and hold the apples if they wanted to. To judge the eating quality (9-point likert scale) each consumer ate one slice (each fruit divided into 10 equal slices) per cultivar. Consumers were allowed to choose the slices on their own.

Statistics. Statistical analyses were performed with XLSTAT® version 2014.4.08 and 2015.1.02

Table 1. Picking date, origin (orchard) of fruits and mean values for the analytical measurements of fruit weight, refractometric index (RI), firmness and acidity. Mean values of N = 20

	Picking date	Orchard	Weight (g)	RI(%)	Firmness (N)	Acidity (g /l)
Ariane	09-16-14	Wädenswil	134.5	12.3	8.7	5.6
Braeburn (Maririred)	10-15-14	Wädenswil	212.0	11.8	7.2	5.7
Ladina	09-13-14	Wülflingen	163.0	12.4	5.7	4.6
Mariella	10-27-14	Wädenswil	178.5	14.1	8.7	6.1
Rustica	10-13-14	Güttingen	140.5	14.4	9.7	7.7

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Table 2. Scale types, labelling and questions used in the questionnaire

	Question	*Scale type* and labelling
Appearance	*„Please evaluate the appearance of the following apples according to your personal liking."*	*9-point likert scale:* 1 – dislike extremely, 9 – like extremely
Eating quality	*„Please evaluate the eating quality in general and the individual parameters of the following apples according to your personal liking."*	*9-point likert scale:* 1 – dislike extremely, 9 – like extremely
Sweetness, acidity and crunchiness		*5-point bipolar just-about-right scale:* 1 – way too little, 3 – just about right, 5 – way too much
Frequency of consumption	*„How often do you eat apples on average?"*	*ordinal:* each day, 1–2× per week, 2–3× per month, less often
Sex	*"Sex:"*	*nominal:* female, male
Age	*"Age:"*	*ordinal:* < 20, 20–29, 30–39, 40–49, 50–59, ≥ 60

(Addinsoft®, Paris, France). A significance level of $\alpha = 0.05$ was chosen for all tests.

RESULTS AND DISCUSSION

Sensory analysis

Table 3 shows the results of the sensory descriptive analysis. Significant differences according to a two-way ANOVA model, including all interactions, were found for green flavour, sweet, sour and bitter taste, astringent, firm, crunchy, cellular, mealy, juicy and chewy mouthfeel. 'Ladina', with its comparably low acidity and firmness, was the cultivar differing the most within the set regarding taste and firmness. All other cultivars were comparably high in acidity and firmness. 'Rustica' was perceived to be the most acidic, 'Mariella' the most firm and crunchy cultivar. Fig. 1 shows a biplot of the principle com-

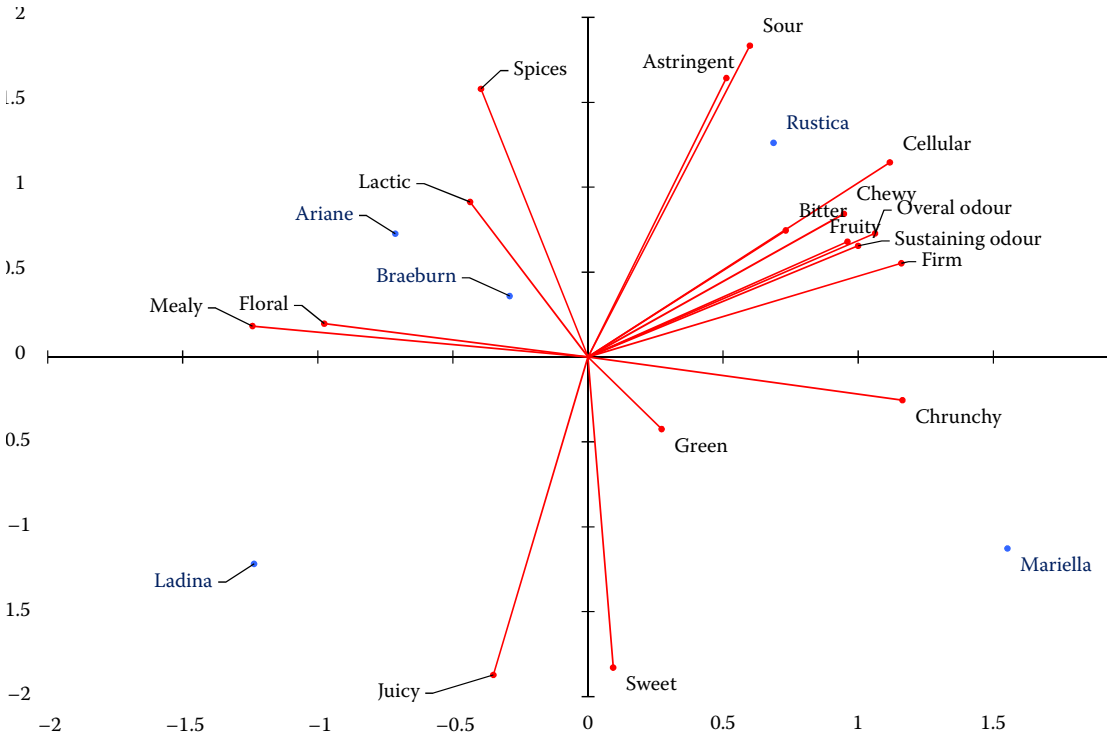

Fig. 1. Biplot of the principle component analysis after varimax rotation for sensory panel data

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Table 3. Sensory descriptive analysis (N = 12)

	Overall odour	Fruity	Green	Floral	Spices	Lactic	Sweet	Sour	Bitter	Astringent	Firm	Crunchy	Cellular	Mealy	Juicy	Chewy	Sustaining odour
Ariane	6.79	5.87	2.70	4.45	3.44	1.30	6.30	8.35	1.20	3.89	9.16	9.02	5.54	1.40	8.19	9.36	6.14
Braeburn	7.06	5.52	4.93	3.34	3.75	1.40	5.32	7.88	1.37	2.76	8.69	8.83	5.53	0.92	9.17	7.65	7.25
Ladina	6.32	5.64	4.36	3.58	3.39	1.02	7.13	4.62	1.46	2.29	5.30	7.54	4.41	1.28	10.16	6.38	5.65
Mariella	7.12	6.08	4.18	2.90	3.09	1.04	7.57	7.08	1.64	3.07	11.21	10.91	6.09	0.59	9.38	9.52	7.06
Rustica	6.96	6.32	4.39	2.77	3.75	1.04	5.01	9.96	2.40	5.41	9.46	8.80	6.50	0.80	7.93	9.08	6.95
P-value	0.74	0.74	0.05	0.07	0.86	0.54	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.01	< 0.01	0.12

P-values refer to the test for difference between products using two-way ANOVA including all interactions

ponent analysis for the sensory data. 68.23% variance could be explained by the first two dimensions. Axis D1 explains to a high degree the variance in textural properties such as mealiness, firmness and crunchiness. Axis D2 explains variance in sweet and sour taste, perceived astringency and juiciness.

Consumer test

Fig. 2 shows the eating quality and appearance liking of the consumers for all five cultivars. Regarding appearance, 'Ariane' reached a significantly higher score of M = 7.31 compared to the other four cultivars, while 'Mariella' reached a significantly higher score of M = 7.45 in terms of eating quality. No previous consumer liking scores have been published for 'Mariella'. The lowest scores in the present study were observed for 'Ladina', which had been tested in two preceding studies with averages of M = 5.85 (Inderbitzin et al. 2015) and M = 5.8 (Leumann et al. 2013). Braeburn' and 'Rustica' had been tested previously in 2011 (Decurtins et al. 2011) where 'Braeburn' showed high acceptance scores for both eating quality and appearance while 'Rustica' was rated significantly lower. In the present study, 'Rustica' (M = 6.69) and 'Ariane' (M = 6.61) reached high acceptance scores, which stands in contrast to the previous findings by Decurtins et al. (2011) and Bonany et al. (2013). These dissimilarities might be explained by differences in sensory context but

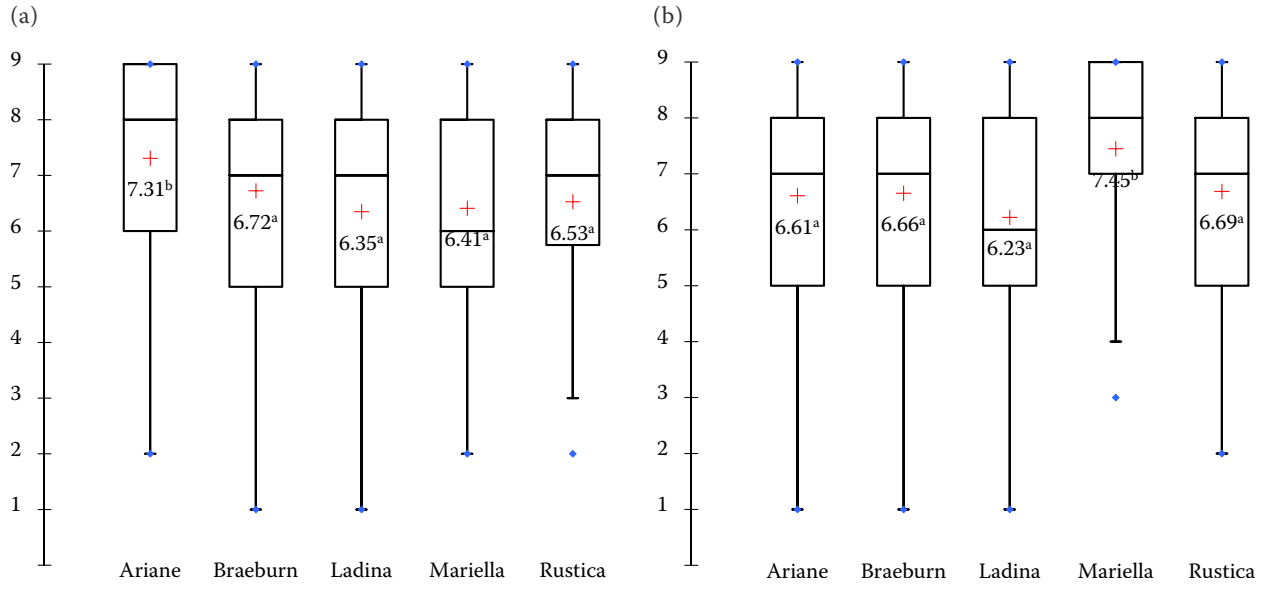

Fig. 2. Consumer scores for (a) appearance and (b) eating quality liking

different letters mean significant differences according to Nemenyis two-sided test procedure, α = 0.05

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also by differing test dates, fruit growing conditions and cultural differences of consumers.

Fig. 3 shows the mean values for the three clusters resulting from the hierarchical cluster analysis of the non-scaled appearance and eating quality scores using Euclidian distances and Ward's method. In terms of appearance, cluster 1 with a high proportion of female consumers (80 female, 31 male) showed ratings greater than 7.0 for all tested cultivars. Members of this cluster did not discriminate and liked the appearance of all apples. Further, there were two clusters with contrasting liking patterns. Cluster 2 preferred the more rustic looking cultivars 'Braeburn', 'Mariella' and 'Rustica', whereas cluster 3 had a preference for 'Ariane' and 'Ladina', two cultivars with a strikingly red skin color. Cluster 2 consisted of 14 female and 18 male and Cluster 3 of 23 female and 21 male consumers.

For eating quality liking, three significantly different clusters with similar age and sex distributions where found. Liking scores for cluster 1 (n = 59) showed positive correlations with juiciness and sweetness and negative correlations with astringency and mealiness, as perceived by the sensory panel (Table 4). Cluster 2 (n = 82) preferred sour cultivars with high firmness, chrunchiness and low in mealiness. Cluster 3 (n = 35) seemed to be particularly sensitive to mealiness and furthermore, liking was highly correlated with firmness and crunchiness.

Effects of sex, age and frequency of consumption versus eating quality and appearance liking were analyzed. Mean appearance-liking values changed in dependence of sex. Significant higher scores for women were found for 'Ariane' (M_{female} = 7.55, M_{male} = 6.90, P = 0.02), 'Rustica' (M_{female} = 6.83, M_{male} = 6.01, P < 0.01) and 'Braeburn' (M_{female} = 7.02, M_{male} = 6.24, P < 0.01). Furthermore, an effect for age in judging appearance liking was observed. 'Ladina' was rated significantly (P < 0.01) better for consumers < 20 a (M = 7.14) compared to consumers in the age groups of 30–40 a (M = 5.41), 40–50 a (M = 5.79) and 50–60 a (M = 5.83) according to multiple

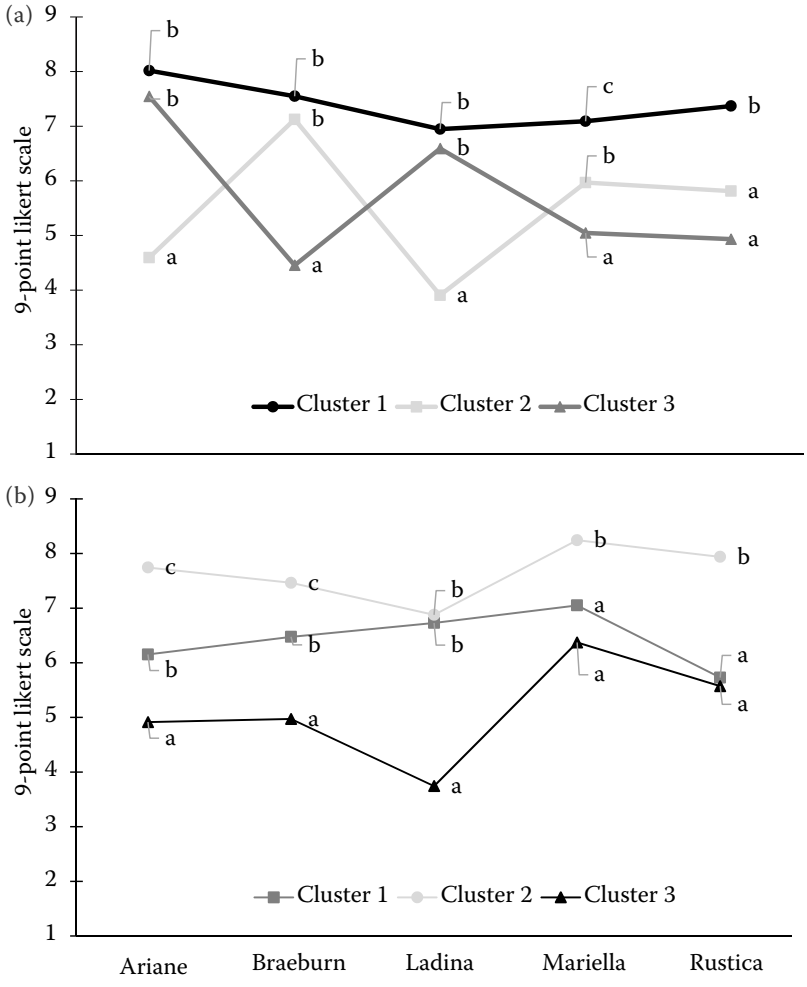

Fig. 3. Mean liking values for the three clusters of consumers resulting out of the cluster analysis for (a) appearance liking and (b) eating quality liking

different letters mean significant differences according to Nemenyis two-sided test procedure, α = 0.05

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Table 4. Coefficients of determination (R^2) for models between eating quality liking and sensory attributes

	Model	Overall (N = 176)	Cluster 1 (n = 59)	Cluster 2 (n = 82)	Cluster 3 (n = 35)
Green	lin	0.06 (–)	0.20 (+)	0.28 (–)	0.10 (–)
Sweet	lin	0.06 (+)	**0.68** (+)	0.01 (–)	< 0.01 (–)
Sour	qdr	0.48	**0.84**	**0.66**	0.58
Bitter	lin	0.01 (+)	0.38 (-)	0.14 (+)	0.13 (+)
Astringent	lin	0.02 (+)	**0.69** (-)	0.29 (+)	0.19 (+)
Firm	lin	**0.80** (+)	< 0.01 (-)	**0.94** (+)	**0.87** (+)
Crunchy	lin	**0.92** (+)	0.15 (+)	**0.73** (+)	**0.74** (+)
Cellular	lin	0.31 (+)	0.34 (-)	**0.72** (+)	**0.61** (+)
Mealy	lin	**0.76** (–)	0.04 (-)	**0.63** (–)	**0.82** (-)
Juicy	lin	< 0.01 (–)	**0.84** (+)	0.22 (–)	0.10 (-)
Chewy	lin	0.46 (+)	0.12 (-)	**0.83** (+)	**0.63** (+)

numbers are in bold if $> \pm 0.60$; only attributes with significant differences for the different cultivars were considered; qdr – quadratic model with negative coefficient; lin – linear model; (+) positive linear correlation; (–) negative linear correlation

pairwise comparisons with a two-sided Steel-Dwass-Critchlow-Fligner test.

A significant effect of the position of the cultivar in the questionnaire was observed. Eating quality liking for 'Ladina' was judged significantly higher according to multiple pairwise comparisons with a two-sided Steel-Dwass-Critchlow-Fligner test ($M_{\text{version 1}} = 7.05$, $M_{\text{version 5}} = 5.50$), in version 1 (first sample) compared to version 5 (subsequent to 'Braeburn') of the questionnaire.

CONCLUSION

The consumer sample in this study preferred the appearance of 'Ariane'. For eating quality, 'Mariella' was liked more than the benchmark 'Braeburn' and therefore seems to be a superior alternative in terms of consumer acceptance. Three distinct clusters for consumer preferences in regard to both, appearance and eating quality, were found. One cluster preferred red skinned cultivars, one preferred more rustic (natural/organic) looking cultivars and one was indifferent. Three clusters, unconnected to the ones found for appearance, were found for eating quality acceptance. Textural properties such as crunchiness, firmness and mealiness showed to be of great importance for 66.5% of the consumer sample (Clusters 2 and 3). One cluster showed a high correlation to firmness and crunchiness, the other cluster to firmness and mealiness. Women liked three of the five cultivars better than men. Age showed an effect for 'Ladina' which was liked better by consumers under twenty years compared to other age groups.

In conclusion, the results suggest that disease resistant or tolerant apple cultivars are valuable alternatives to present market leaders in Switzerland. Further research is needed regarding the extrapolation of the present data to other countries. Additionally, factors such as storage performance and other economic factors need to be integrated in such analyses in the near future.

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