Revista Mexicana de Ciencias Agrícolas

DOI: https://doi.org/10.29312/remexca.v14i5.3197

Physical and chemical characterization of the fruits of three varieties of *Prunus persica* L. Batsch in Tlaxcala

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Abstract

Peach [*Prunus persica* (L.) Batsch] is considered one of the most important fruits worldwide and in Mexico. The research was conducted in the municipality of Altzayanca, Tlaxcala, in 2019. The varieties Escarcha, Lucero and Amarillo criollo are produced in the locality, with an important acceptance by the local and regional consumer. The objective was to evaluate the physical and chemical characteristics in fruits of three varieties of peach through weight, size, firmness, pH, electrical conductivity, total soluble solids (TSS), titratable acidity (TA) and maturity index (TSS/AT ratio), characteristics that will allow determining their postharvest disposition. From each variety, four trees were selected at random and from each tree 10 fruits, in total 40 fruits per variety. Data were subjected to tests of normality and homogeneity of variance to perform an Anova and mean comparison by the Tukey test ($p< 0.05$), in addition to a principal component analysis (PCA). The results showed that, in the fruits of the three varieties, the sugar content (°Brix > 10) for the market is adequate, in the variable of firmness the average value was 15.1 N, according to Mexican regulations, both values are suitable for making preserves. Through the PCA, the size, maturity index and firmness were determinants in the variation between the varieties, in conclusion, the aforementioned characteristics can be considered by producers as good indicators of maturity and flavor in the postharvest stage.

Keywords:

maturity, peach, postharvest.

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Introduction

Prunus persica (L.) Batsch is widely grown in temperate climates, has great standards in the international market, is the third most important temperate climate fruit behind apple and pear. More than 90% of the world's production is intended fresh. The fruits are characterized by their content of vitamin C, carbohydrates, such as fructose, sorbitol, glucose and sucrose, as well as oxalic, citric, isocitric, malic, fumaric and shikimate acids (Nowicka *et al*., 2019). Peach is a climacteric fruit, it means that once the fruits are harvested, they continue with metabolic activity, related to the maturation process where energy is produced by the oxidation of sugars and organic acids, which leads to the formation of water and CO_2 (Martínez-González *et al*., 2017).

In addition to containing plant hormones such as ethylene, it regulates the main molecular, biochemical and physiological processes during fruit maturation, reflected in the increase in degrees Brix, color changes at the level of epidermis and pulp, decrease in acidity and firmness of the fruit, at the level of carbohydrates, in the conversion of starch to soluble sugars, which increases the sweet flavor of the fruits, there is also degradation of polymeric carbohydrates, starch and cellulose (Hiwasa-Tanase and Ezura, 2014).

In addition to the above, in the fruit, the firmness and total soluble solids (TSS) cause changes in the organoleptic variables as time passes and senescence begins, which generates the greatest postharvest losses, due to the weakening of the structure of the fruit that is reflected in a lower firmness and causes a greater susceptibility to mechanical damage and the attack of pathogens (Farias *et al*., 2017). Abbasi *et al*. (2019) point out that firmness is the most used indicator to determine the potential shelf life of fruits at postharvest and for decision-making in selection, packaging and transport operations. Buitrago-Guacaneme *et al*. (2015) mention that the TSS are also an important quality criterion since the determination of their accumulation in the fruit together with the titratable acidity (TA) allow estimating the time of harvest; whereas the ratio of TSS/TA is an indicator of the flavor of the fruit during maturation (Nowicka *et al*., 2019).

In Mexico, the main peach-producing states are: Zacatecas, Michoacán, State of Mexico and Tlaxcala, the latter ranks ninth nationally with an area of 1 160 ha planted, the largest production is concentrated in the northwest of the state, the fruits are intended for the local and regional market. One of the important cultivars is semi-freestone Escarcha, of intermediate maturation in early July (Fernández-Montes *et al*., 2011), on the other hand are Amarillo criollo and Lucero, of late maturation in September.

The varieties are of great importance for their organoleptic characteristics, the production in 2020 was 3 979 t with a price of $ 25 t^{-1} (SIAP, 2020), in addition, they are varieties that have adapted to the local climate, which encourages the producer to develop an adequate management that guarantees a greater volume and quality (Fernández-Montes *et al*., 2011).

For the sale of the fruits, characteristics that allow them to last on the shelf are required. Most producers are unaware of their product information when harvesting, while the canning industry requires cultivars with specific characteristics of texture, firmness and pulp color (Abbasi *et al*., 2019). Therefore, harvesting fruits with ideal commercial values is an economic guarantee for the producer.

The demanded characteristics of maturity are: firmness and flavor, which allow estimating the acceptance it will have in the market (Altube *et al*., 2017). Therefore, the objective of this research was to evaluate the physical and chemical characteristics in fruits of three varieties of peach in the state of Tlaxcala, which will allow determining their postharvest disposition, under the hypothesis that there are differences between the varieties.

Materials and methods

The Escarcha variety is from the locality of Concepción Hidalgo, located in the municipality of Altzayanca, Tlaxcala (19° 23' 30.61" north latitude and 97° 49' 35.84" west longitude), with an average temperature of 14 °C and a rainfall of 600 mm. The varieties Lucero and Amarillo criollo

DOI: https://doi.org/10.29312/remexca.v14i5.3197

are produced in the locality of San José Xicohténcatl, Huamantla, Tlaxcala (19° 21' 27.8" north latitude and 97° 49' 52. 26" west longitude), at 16 °C and 700 mm of rainfall (INEGI, 2009) (Table 1). The soils of both sites have a loamy sandy texture, bulk density of 1.11 to 1.25 g cm^{-3}, neutral pH and an organic matter content less than 1.01% (García-Gallegos *et al*., 2020).

Table 1. Management and yield of three varieties of peach in Tlaxcala.

Variety	PD ha^{-1}	PA	Y (kg $tree^{-1}$)	ANF $tree^{-1}$	Management†
Escarcha	785	adult	13.40	156	Ir, F, WC, AM, C, CF
Amarillo criollo	1 000	adult	13.04	183	DIr, F, WC and CF
Lucero	900	adult	10.5	99	R, F, WC, CF

PD= planting density; PA= plant age; Y= yield; ANF= average number of fruits; Ir= irrigation; DIr= drip irrigation; R= rainfed; F=furrow; WC= weed control; C= compost (application every cycle, in November); AM= anti-hail mesh; CF= chemical fertilization (urea or ammonium nitrate at flowering; Triple 17, after harvest); †= information provided by producers.

Since the maturation of the varieties differs, the harvest of the fruits for Escarcha was in July; while, for Lucero and Amarillo criollo in September. Four trees per variety were randomly selected and from each tree, 10 fruits without mechanical damage and in good phytosanitary conditions were collected early in the morning, in total 40 peaches per variety, deposited in cardboard pulp trays for immediate transfer to the laboratory.

Within the physical characteristics, the following were determined: weight of each fruit was measured with a digital triple beam balance (Adam®), the size was measured with a RoHS® digital Vernier based on the major diameter (polar diameter) and the minor diameter (equatorial diameter) by the NMX-FF-009-SCFI-1982 (DOF, 1982), the firmness was measured with a texture meter (TAXT Plus®), coupled to the Stable Micro Systems software, with a tip of 3 mm in diameter, which corresponded to the maximum force in g that was converted to kg and then multiplied by the acceleration constant (9.866 m s^{-2}) resulting in the force in Newton (N) based on the NMX-FF-060-SCFI-2009 (DOF, 2009).

For the chemical characteristics, the fruits were removed the epicarp and immersed in water at 100 °C for 40 s, then in cold water at 5 °C and thus inhibit enzyme activity; subsequently, the endocarp was removed and the mesocarp was crushed with an electrical processor (Hand Blender®), the juice was extracted by vacuum filtration.

The pH and electrical conductivity (EC) were determined in juice in a ratio 1:1 v/v (water/juice), with a potentiometer (Conductronic®) and a conductivity meter (ExStik® II model EC500) (AOAC, 1990). The TSS were quantified with a digital benchtop refractometer (Atago® model 1T), a refractive index and a value in °Brix were obtained, it was previously calibrated with 2 drops of distilled water, the TA was determined in a ratio 1:1 v/v (water/juice) by titration, titrated with NaOH 0.1 N and phenolphthalein as an indicator, the formula by López and Argaiz (1993) was used, they refer to the data as acidity (% citric acid) = (V_{NaOH} x N_{NaOH} x meq citric acid/V) x 100. Where: V_{NaOH}= volume of NaOH in the titration; N_{NaOH}= normality NaOH (0.1 N); meq citric acid= 0.064 g citric acid; V= volume of the sample; in addition, the maturity index (MI) of the fruits was estimated by dividing the values of the TSS (°Brix) by the percentage of citric acid that corresponds to the TA (Abbasi *et al*., 2019).

The data obtained were subjected to the tests of normality of Shapiro-Wilks (*p*> 0.05) and homogeneity of variances of Levene (*p*> 0.05), once the assumptions were met, the Anova was performed under the linear model: $Y_{ij} = \mu + (_i + (_{ij}$. Where: Y_{ij}= response of the j-th repetition of the i-th treatment; $(_i$ = effect of treatment i; $(_{ij}$= random error associated with observation Y_{ij}. Then a Tukey test (p≤ 0.05) to identify differences between varieties. A Pearson correlation analysis (p≤ 0.05) was performed, and a principal component analysis (PCA) was performed to determine the

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degree of association of fruit characteristics and varieties. This using the statistical software Info Stat version 2008 (Di Rienzo *et al*., 2008).

Results and discussion

In the weight of the fruit, differences were observed between varieties (*p*# 0.05), the Lucero variety presented the highest weight (Table 2) and was the one that had a yield per tree of 10.5 kg ha^{-1} and 99 fruits $tree^{-1}$, compared to the varieties Escarcha and Amarillo criollo (Table 1). However, the values were lower than that reported for fruits of the Dorado variety (181 g), although it is important to consider that the weight decreases at postharvest due to the loss of moisture and temperature during storage or transport (Africano *et al*., 2016). Sun *et al*. (2018) report a reduction of 2.43% in the varieties Sugar Top and Okubao, once harvested the weight loss at 28 days was 6.4, 7.6, 8.4 and 8.8% stored at 0, 2, 5 and 8 °C, respectively, which can happen with the varieties analyzed.

Regarding the polar diameter, there were significant differences between the varieties, the same pattern as in the weight occurred ($p \leq 0.05$) (Table 2). According to the classification by size indicated by the NMX-FF-060-SCFI-2009 (DOF, 2009), the fruits evaluated in this study are optimal for fresh consumption. Díaz-Martínez *et al*. (2017) report, for landrace-type peach of Santiago Papasquiaro, Durango, a polar diameter of 54.92 mm, a value higher than those obtained; whereas the equatorial diameter of 52.48 mm was lower than Escarcha and Lucero.

As for the values of firmness, it was obtained that the Lucero cultivar was significantly higher, followed by Amarillo criollo and Escarcha ($p \leq 0.05$) (Table 2). Nonetheless, these values are lower than indicated by the NMX-FF-060-SCFI-2009, which establishes an overall firmness of 34.32 N, so the marketing time of the varieties evaluated could be restricted. Africano *et al*. (2016) report, for the Dorado variety, a firmness of 12.81 N, higher than the Escarcha variety and lower than the other two varieties.

Table 2. Physical characteristics of fruits of *P. persica* L. Batsch in Tlaxcala, Mexico.

Variety	Weight (g)	PDi (mm)	EDi (mm)	Firmness (N)
Escarcha	84.99 ±9.02 b	50.01 ±1.46b	53.1 ±2.4 a	8.74 ± 2.72 c
Amarillo criollo	63.43 ±7.66 c	46.69 ±0.94 c	47.17 ±2.1 b	14.43 ± 1.99 b
Lucero	106.95 ±3.71 a	54.65 ±1.6 a	56.23 ±0.87 a	22.13 ± 1.98 a

PDi= polar diameter; EDi= equatorial diameter. Means ± standard deviation. Different letters by column indicate means significantly different from each other, according to the Tukey test ($p \leq 0.05$); n= 40.

For the Flordaking variety, a firmness of 36.35 N at postharvest is reported and it decreases to 8.73 N at the sixth week. Abbasi *et al*. (2019) point out that the firmness of peach fruits tends to decrease as maturation progresses. The softening of the fruit occurs as a process of modifications in the structure of the cell wall, where the depolymerization of glucans and solubilization of pectin occurred; likewise, the decrease in firmness can be related to a high concentration of nitrogen in the fruit (Santiago-Mejía *et al*., 2008), which will depend on the variety and management provided by the producer (Table 1).

In juice, the pH of the Escarcha variety was more acidic with respect to the values obtained in Amarillo criollo and Lucero ($p \leq 0.05$) (Table 3). Miranda *et al*. (2019) report, for the Chimarrita variety, a value of 3.2. The NMX-F-034-1982 (DOF, 1982) establishes a pH of 3.5 as a minimum and 4.2 as a maximum for the preparation of peaches in syrup, therefore, the varieties analyzed are not suitable for that purpose; however, the standard allows citric acid to be added as an acidulant when it is required to reach the required pH.

In the electrical conductivity (EC), the average values were different between the varieties, the highest was obtained by Escarcha ($p \leq 0.05$) (Table 3), even so, lower compared to what was reported by Bonazzola *et al*. (2007) for the varieties Flordarking and Forastero (5.10 and 5.40 mS

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cm^{-1}). One of the most abundant elements in peach pulp is K, followed by Ca, Mg and Na, but its concentration may decrease during fruit maturation (Dabbou *et al*., 2017).

Table 3. Chemical characteristics of fruits of *P. persica* L. Batsch, Tlaxcala, Mexico.

Variety	pH	EC (mS cm^{-1})	TA (%)	TSS (°Brix)	TSS:TA (index)
Escarcha	4.3 ±0.12 b	1.88 ±0.11 c	0.35 ±0.06 a	11.43 ±0.6 b	33.67 ±5.8 b
Amarillo criollo	4.5 ±0.2 a	2.75 ±0.33 b	0.25 ±0.1 ab	10.53 ±1.11 b	46.4 ±14.28 b
Lucero	4.8 ±0.25 a	3.61 ±0.26 a	0.13 ±0.03 b	13.53 ±0.41 a	108.27 ±33.66 a

Means ± standard deviation. EC= electrical conductivity; TA= titratable acidity; TSS= total soluble acids. Different letters by column indicate means significantly different from each other, according to the Tukey test (p< 0.05); n= 40.

For titratable acidity (TA), the values showed that the Escarcha variety is significantly higher with respect to Lucero (*p*# 0.05) (Table 3). The three varieties analyzed had values lower than those evidenced by Africano *et al*. (2016) for the Dorado variety, with a percentage of 0.87%, while in the Flavorcrest variety, it went from 0.96 in the first harvest to 0.74% in the last of 2010, and from 0.47 to 0.5% in 2012 (Altube *et al*., 2017).

In the same variety, Abbasi *et al*. (2019) report an acidity percentage of 1.09 at the time of harvest and it decreased to 0.63% at the sixth week of storage, higher than what Tlaxcala fruits had. The predominant organic acids in the fruits of *Prunus persica* (L.) Batsch are malic and citric acids, which decrease with maturation, these acids represent 65% of the total content of organic acids in the fruit, in addition to oxalic, fumaric and isocitric acid (Nowicka *et al*., 2019).

Regarding TSS, the value of the Lucero variety was significantly higher with respect to Escarcha and Amarillo criollo (*p*# 0.05) (Table 3). The sugar content in the fruits is within what is established by the NMX-FF-060-SCFI-2009 (DOF, 2009), which, as a maturity specification, stipulates that the minimum TSS content in fruits of all peaches must be 10 °Brix. The Lucero variety had a higher amount of sugars than reported by Africano *et al*. (2016) for the Dorado variety, with 11.6 °Brix; Farias *et al*. (2017) report values of 11.45 °Brix for the Cascata 1513 genotype, increasing to 12.66 °Brix after 10 days of storage, similar to the Escarcha variety.

In mature fruits, soluble solids include: oligosaccharides, polysaccharides, organic acids, pigments and tannins, among others, but their content is usually higher in fruits of intense color (Nowicka *et al*., 2019), that when the degradation process occurs, soluble sugars are generated, which increases the TSS in the fruit (Buitrago-Guacaneme *et al*., 2015).

In the case of climacteric fruits, the respiratory rate increases at maturation to produce the energy necessary for the hydrolysis of starch that leads to the synthesis of monosaccharides such as glucose and fructose between 30 and 50%, in less quantity sucrose, which represented 1.5 and 5% of the total weight of the fruit (Agustí, 2013). When establishing the TSS:AT ratio to obtain the maturity index, the Lucero variety had a significant increase, as a result of the reduction of the TA and increase in the TSS (Table 3).

The fruits of the Escarcha variety had an index of 33.67, this relationship is an indicator of fruit maturity, this variety is of intermediate maturation and due to its semi-freestone condition, the time of harvest of the fruit could be earlier than that established by the producer. Marques-Costa *et al*. (2008) point out that a maturity index for peaches ranges from 16.5 to 36; nevertheless, values of 25 or less indicate an optimal maturity for harvesting, according to this value, the fruits of the three varieties were harvested after the optimal point.

Leonel *et al*. (2014) report a maturity index of 12.5 to 21.4 for climacteric fruits such as peach. Africano *et al*. (2016) obtained a maturity index of 12.41 for the Dorado variety, values lower than that reported in this study for the varieties of Tlaxcala. In three-year-old trees of the August Flame variety, a maturity index of 1.4 is reported, increasing as the storage time progresses to 2.76 at the fourth week (Ceccarelli *et al*., 2019).

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The differences between the varieties (Tables 2 and 3) are the result of genotype, but it is also important to mention that agroecological factors such as moisture, temperature, management (Table 1) and possible effects of pests and diseases influence the characteristics evaluated and the productive potential and quality of the fruit (size, shape, sugar content, acidity and postharvest life) (Fernández-Montes *et al*., 2011). On the other hand, Nowicka *et al*. (2019) indicate that the TSS:AT ratio can also be used to classify peach fruits based on their flavor, thus a maturity index of 5 to 7 they are acidic, 17 to 24 bittersweet and 31 to 98 sweet, based on this classification, the fruits of the three varieties analyzed are considered sweet, although the Lucero variety exceeded the highest value of the classification by 10.27 units, this may indicate that it is a fruit harvested after the optimal time and therefore, its postharvest life will be affected.

The correlation analysis shows that, the greater the polar and equatorial diameter of the fruit, the greater the weight. An increase in the firmness of the fruit resulted in a higher electrical conductivity and therefore an increase in the pH value (Table 4). At a lower acidity, an increase in the maturity index, which coincides with Buitrago-Guacaneme *et al*. (2015), who report that this TSS:AT ratio shows an increase during fruit maturation, resulting from reduced acidity and increased TSS, which is reflected in the Lucero variety.

Table 4. Pearson correlation coefficients for the physicochemical characteristics of the fruits of three varieties of *P. persica* L. Batsch, Tlaxcala, Mexico.

	Weight	PDi	EDi	Firmness	pH	EC	TA	TSS	TSS:TA
Weight	1								
PDi	0.99*	1							
EDi	0.98*	0.96*	1						
Firmness	0.58*	0.64*	0.45ns	1					
pH	0.2ns	0.28ns	0.03ns	0.86*	1				
EC	0.45ns	0.53*	0.31ns	0.95*	0.89*	1			
TA	-0.25ns	-0.45ns	-0.26ns	-0.75*	-0.75*	-0.69*	1		
TSS	0.77*	0.77*	0.7*	0.67*	0.44ns	0.66*	-0.42ns	1	
TSS:TA	0.6*	0.64*	0.49ns	0.79*	0.71*	0.74*	-0.84*	0.74*	1

PDi= polar diameter; EDi= equatorial diameter; EC= electrical conductivity; TA= titratable acidity; TSS= total soluble solids. *Pearson correlation coefficient ($p < 0.05$); ns= not significant.

The principal component analysis (PCA) shows that the total variability is explained by the components PC1 (77%) and PC2 (23%), these two components explain 100% of the total variation of the data. The characteristics that indicate a greater weight in the PC1 maturity index, TSS, TA and firmness. The PC2 is explained by equatorial diameter and pH (Table 5 and Figure 1).

Table 5.Principal components of the characteristics of the fruit of three varieties of *P. persica* L. Batsch, Tlaxcala, Mexico.

Indicator	PC1	PC2
Weight	0.32	0.38
Polar diameter	0.33	0.33
Equatorial diameter	0.27	0.48
Firmness	0.35	-0.26
pH	0.29	-0.46
Conductivity	0.34	-0.31
Titratable acidity	-0.35	0.28
TSS	0.36	0.24
Maturity index	0.38	-0.07

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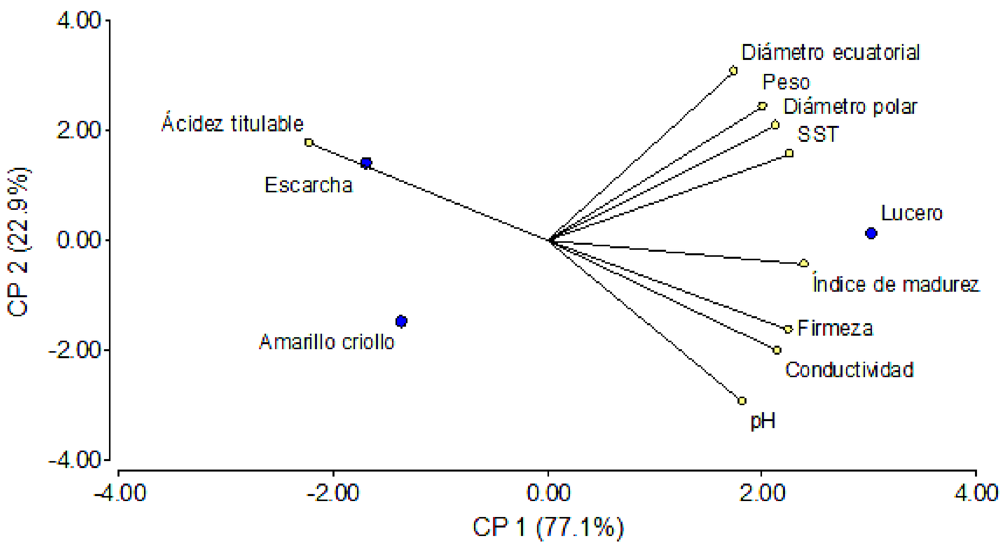
Figure 1. Biplot of the physicochemical characteristics of the fruit in three varieties of *Prunus persica* (L.) Batsch in Tlaxcala.



Conclusions

Based on the size, the three varieties meet the standards of Mexican regulations, the firmness indicates that the harvest times of the fruits are not the optimal of the producer. Due to the chemical characteristics, the fruits are suitable for preparing preserves. With the PCA, it was determined that the size, maturity index and firmness for the Lucero variety are determinants for its postharvest quality and in the case of the Escarcha variety, it was the titratable acidity. Therefore, it is important that producers consider these variables to establish the optimal times for harvesting the fruit, as well as the management in the plots (fertilization, irrigation, control of weeds, pests and diseases).

Acknowledgements

We thank the peach producers for the support to carry out this work, and CONACYT for the scholarship provided for J. A. Chávez Gómez.

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Revista Mexicana de
Ciencias Agrícolas
REMEXCA

DOI: https://doi.org/10.29312/remexca.v14i5.3197

Physical and chemical characterization of the fruits of three varieties of *Prunus persica* L. Batsch in Tlaxcala

Journal Information
Journal ID (publisher-id): remexca
Title: Revista mexicana de ciencias agrícolas
Abbreviated Title: Rev. Mex. Cienc. Agríc
ISSN (print): 2007-0934
Publisher: Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias

Article/Issue Information
Date received: 01 April 2023
Date accepted: 01 July 2023
Publication date: 01 August 2023
Publication date: July 2023
Volume: 14
Issue: 5
Pages: 085-094
DOI: 10.29312/remexca.v14i5.3197

Categories

Subject: Articles

Keywords:

Keywords:

maturity
peach
postharvest

Counts

Figures: 1
Tables: 5
Equations: 0
References: 27
Pages: 10