Materials Today: Proceedings xxx (xxxx) xxx

Contents lists available at ScienceDirect

Materials Today: Proceedings

journal homepage: www.elsevier.com/locate/matpr

Simultaneous analysis of octylmethoxycinnamate and butylmethoxydibenzoylmethane in sunscreen products by a validated UV-spectrophotometric method

S. Lavakumar [a,b], P.A. Vivekanand [c], A.A.M. Prince [a,*]

[a] Department of Chemistry, Ramakrishna Mission Vivekananda College, Chennai 600004, Tamilnadu, India
[b] CavinKare Research Centre, Chennai 600032, Tamilnadu, India
[c] Department of Chemistry, Savitha Engineering College, Thandalam, Chennai 602105, Tamilnadu, India

ARTICLE INFO

Article history:
Available online xxxx

Keywords:
SPF
Sunscreen products
Butylmethoxydibenzoylmethane (BMDM)
Octyl methoxycinnamate (OMC)
Analytical Method development

ABSTRACT

In this paper we report, an accurate, rapid, simple and an inexpensive method for the determination of Octyl methoxycinnamate and Butylmethoxydibenzoylmethane in sunscreen products using UV–Vis spectrophotometer. The method is validated as per ICH guidelines. The solvent system is methanol, with λ_{max} of 310 nm for OMC and 357 nm for BMDM, linearity range of OMC is 1.01 to 10.12 μg/ml (R^2 = 0.9997) and BMDM is 1.00 to 10.02 μg/ml (R^2 = 0.9996), The % recovery of OMC (98.04–99.69) and relative standard deviation (%RSD, 0.54) and % recovery of BMDM (95.77–97.31) and relative standard deviation (% RSD, 0.55), highlights the accuracy of the method developed. The method is compatible to wide variety of products composed of oil in water and water in oil emulsions containing low, intermediate, and high OMC and BMDM levels (1%, 2%, and 4%) gave good recovery. This method is suitable for meeting dynamic need of formulation development and suitable for quality assurance of all types of skincare products containing OMC and BMDM.

Selection and peer-review under responsibility of the scientific committee of the National Conference on Chemistry and Materials-2019.

1. Introduction

The UV radiation from sun and other sources are very harmful to the sensitive skin, which can cause erythema, edema, hyper and hypo pigmentation, these damages lead to melanoma [1,2]. Consumers use over the counter (OTC) cosmetic products to overcome these problems. All the sunscreen products carry UV filters to protect the users from UV radiation from the sun. Such products typically contain organic or inorganic compounds as UV filters or a mixture of both. The most commonly used organic UV filters are OMC and BMDM. The OMC is used at maximum level of 10% and BMDM is used at maximum level of 5% in sunscreen formulations [3]. European Union allowed levels of OMC and BMDM are 10% and 5% and USFDA allowed limits of OMC and BMDM were 7.5% and 3% respectively [4–6]. A stable sun care formulations meeting robust quality standards are necessary to ensure desired UV damage protection [7]. Assay of organic sun care actives including OMC and BMDM are usually assessed using HPLC [7–10]. HPLC based analysis required more investment, expertise, high method development time, etc., all these factors add to the cost of analysis per sample.

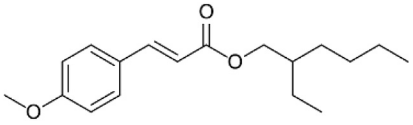
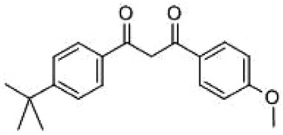
Development of a cost effective, simple, rapid, precise, accurate and practically feasible method will be of benefit to cosmetic and pharmaceutical industry, this can replace currently practised assay methods [7,11,12]. The UV based analysis method for OMC is already reported, however, the practical use of this method is very limited [13]. This is specific to sun care products containing OMC as a single active ingredient. Most of the sunscreen products available in the market contain both UVA and UVB protecting organic sunscreen ingredients.

We here in report a simultaneous, simple, cost-effective method using UV–Vis spectrophotometer for the analysis of OMC and BMDM. *INCI name, structure and maximum absorption of OMC and BMDM used in formulation are presented in Table 1. The method has been validated in accordance with the International Council for Harmonization (ICH) and Association of Official Analytical Chemists (AOAC) guidelines [14,15], with validated repeatabil-

* Corresponding author.
E-mail address: aamprince@rkmvc.ac.in (A.A.M. Prince).

https://doi.org/10.1016/j.matpr.2020.07.025
2214-7853/
Selection and peer-review under responsibility of the scientific committee of the National Conference on Chemistry and Materials-2019.

Table 1
INCI name, chemical structure and maximum absorption of OMC and BMDM.

INCI name	chemical structure	λ_{max} (nm)
Octylmethoxycinnamate (OMC)		310
Butylmethoxydibenzoyl methane (BMDM		357

*INCI: International nomenclature of cosmetic ingredients.

ity in two types of dosage forms: oil in water (O/W) and water in oil (W/O) emulsions. The suggested method of simultaneous estimation of two widely used UV actives based on UV spectrometry can be used for routine sun care product testing protocols.

2. Materials and methods

The OMC and BMDM/BMDBM were purchased from Sigma-Aldrich. Analytical grade solvents were used for the method development. Cosmetic grade ingredients and sterile DM water were used to prepare the O/W and W/O emulsions compositions. A UV–Visible spectrophotometer (UV-1601, Shimadzu, Tokyo, Japan) was used to record the absorbance.

2.1. Preparation of O/W emulsion

(see Table 2).

2.2. Phase-1

Cetyl alcohol, Potassium cetyl phosphate and C12-15 alkyl benzoate were weighed as mentioned above into a glass beaker and heat up to 75 °C, under hot condition, add required quantities of UV active ingredients (Table 3).

2.3. Phase-2

Carbopol 940 was dispersed in water under vigorous stirring, after ensuring uniform dispersion, required quantity of mixture is added to phase-1 ingredients along with predetermined quantities of water, followed by addition of 0.2 g of Triethanolamine under vigorous stirring. Stirring continued for 15 min at room temperature.

2.4. Preparation of W/O emulsion

All the organic ingredients except the UV actives were melted together at 75 °C, after ensuring complete melting. $MgSO_4{\cdot}7H_2O$ is dissolved in sterile DM water added under vigorous stirring with simultaneous addition of required quantities of OMC and BMDM, stirring continued for 30 min at room temperature.

Table 2
Ingredients of O/W emulsion.

Emulsion	Ingredient	%w/w
O/W	Cetyl alcohol	4
	Potassium cetyl phosphate	3
	C12-15 alkyl benzoate	15
	OMC	1.00, 2.00, 4.00
	BMDM	1.00, 2.00, 4.00
	Carbopol 940	0.2
	Triethanolamine	0.2
	DM water	qs to 100

Table 3
Ingredients of W/O emulsion.

Emulsion	Ingredient	%w/w
W/O	Bees wax	1
	PEG-30 dipolyhydroxy stearate	3
	C12-15 alkyl benzoate	15
	OMC	1.00, 2.00, 4.00
	BMDM	1.00, 2.00, 4.00
	Glycerin	5
	Magnesium sulphate heptahydrate	0.8
	DM water	qs to 100

3. Validation of OMC and BMDM analysis method

3.1. Specificity of OMC and BMDM

3.1.1. Solvent selection

0.1 g of OMC/BMDM was weighed into a 100 ml volumetric flask and added acetonitrile or ethanol or methanol and made up to the mark. 0.5 ml of this solution was transferred into another 100 ml volumetric flask, and diluted with each solvent separately (5 μg/ml). Absorbance pattern of each solution was recorded from 200 to 400 nm. The best solvent was chosen as methanol based on UV_{max} and absence of interference effects by solvent. The stock solutions (1.012 mg/ml for OMC and 1.0 mg/ml for BMDM) were prepared and a serial dilutions (1, 2, 4, 6, 8, and 10 μg/ml), were made for validating the analysis.

Validated parameters such as linearity, range, accuracy, and precision were assessed at six different concentrations (1, 2, 4, 6, 8, and 10 μg/ml), and the absorbance was recorded at 310 nm for OMC and 357 nm for BMDM. Based on six replicate analyses performed, the linearity for OMC/BMDM were established with a calculated regression correlation (r) of 0.9997 for OMC and (r) of 0.9996 for BMDM along with calculated recovery (%) and relative standard deviation (%RSD).

3.2. Validation of sunscreen products analysis method

3.2.1. Specificity

4 g of each type of cosmetic formulations of base was weighed into 100 ml volumetric flasks, separately, then made up to mark using methanol. The solution was sonicated for 5 min and filtered through Whatman.41 filter paper. 1 ml of the filtered solution was

Please cite this article as: S. Lavakumar, P. A. Vivekanand and A. A. M. Prince, Simultaneous analysis of octylmethoxycinnamate and butylmethoxydibenzoylmethane in sunscreen products by a validated UV-spectrophotometric method, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2020.07.025

pipetted into 100 ml volumetric flask and diluted with methanol and made up to the mark. The λ_{max} was determined as described in the specificity of OMC/BMDM analysis.

3.2.2. Accuracy and precision

Six 100 ml volumetric flasks were taken, each type of cosmetic formulation base (4.0 g of 1% OMC/BMDM, 2.0 g of 2% OMC/BMDM, and 1.0 g of 4% OMC/ BMDM) were weighted into them and diluted with methanol up to the mark and mixed thoroughly under sonication for 5 min. The stock OMC/BMDM solution (4 mg/ml, 10 ml) in separate 100 ml volumetric flask and adjusted to them with methanol and mixed thoroughly. The solution was filtered through Whatman.41 filter paper. 1 ml of the filtered solution was pipetted into 100 ml volumetric flask and diluted with methanol and made up to the mark. UV absorbance was measured as described at 310 nm for OMC and 357 nm for BMDM. Six replicates were performed concurrently.

3.2.3. Repeatability of the method

Six 100 ml volumetric flasks were taken, each type of cosmetic formulation (4.0 g of 1% OMC/BMDM, 2.0 g of 2% OMC/BMDM, and 1.0 g of 4% OMC/BMDM) were weighted into them and diluted with methanol up to the mark and mixed thoroughly under sonication for 5 min. The solution was filtered through Whatman.41 filter paper. 1 ml of the filtered solution was pipetted into 100 ml volumetric flask and diluted with methanol and made up to the mark. The solutions were prepared as described for accuracy validation and UV_{max} absorbance at 310 nm and 357 nm was measured and the experiments were repeated six more times.

4. Results and discussion

4.1. Validation of OMC and BMDM analysis method

The ICH and AOAC guidelines were used to validate UV-spectrophotometer based simultaneous determination of OMC and BMDM as a pure compound mixture and in the cosmetic formulation matrix [12,13].

Three solvents namely acetonitrile, ethanol and methanol were tested to select the most suitable solvent for the method development based on λ_{max} values and absence of solvent interference. Methanol was selected as the suitable solvent for the study. It gives λ_{max} ($\leq$1.1) for OMC and BMDM mixture (1, 2, 4, 6, 8, and 10 μg/ml). λ_{max} values of 310 nm and 357 nm respectively. Further method validation was performed using this specificity profile.

4.2. Linearity and range

As per ICH and AOAC guidelines, at six different concentrations, validated parameters were assessed for OMC and BMDM (1, 2, 4, 6, 8, and 10 μg/ml) as shown in Table 4. This range is having coefficient of determination of 0.9997 and 0.9996 for OMC and BMDM respectively. These values are higher than 0.995, which indicates the precision and acceptable linearity of the method. Fig. 1 shows the spectrum of different concentration of OMC and BMDM standard solutions and the calibration curve obtained by plotting the absorbance of OMC and BMDM against the concentration are presented in Fig. 2. The results are almost equal to reported values for OMC analysis by HPLC (R^2 = 0.999) with higher detection limit of 10–40 μg/ml [6].

4.3. Accuracy and precision

% Recovery of OMC and BMDM based on six repeated analyses highlight the accuracy of the method developed. Recoveries of OMC and BMDM 98.04–99.69 and 95.77–97.31% respectively as given in Table 5 demonstrate repeatability of the protocol followed and disclosed here. It is important to note that the recovery % is within the AOAC set ranges. Precision of the method was explicitly evident based on % RSD. The % RSD of OMC and BMDM is 0.54 and 0.55 respectively. These values are well within the ICH allowed limits of 1%. More importantly this UV based method shows better reproducibility for OMC determination in comparison to HPLC and micellar electrokinetic capillary chromatography (MECC) with % RSD 0.59 and 1.89 respectively with wider linear range of 0.02–20 μg/ml and 0.25–50 μg/ml[8].

5. Validation of omc , bmdm analysis method in sunscreen products

Cosmetic formulations containing OMC and BMDM as sunscreen agents in two different dosage forms O/W and W/O emulsions were prepared and SPF determined [16] to have UVA and UVB absorption efficacies of 75–85%, based on both the products were further analysed for OMC and BMDM content.

6. Repeatability of the method

In both the products, absorbance values in methanol were recorded between 200 and 400 nm, the combination and the products display smooth baseline, other ingredients in the product were not imparting any interference over the analytical range. The base was weighted (4 g) for 4 mg/ml OMC and BMDM that was calculated from minimum 1% OMC and BMDM in the product. Thus, the validated analytical method is, specific for OMC and BMDM determination in these emulsion systems. The accuracy of OMC and BMDM levels in these cosmetic formulations were further validated by weighing, conducted on the basis of OMC and BMDM content at different amounts as described in the Materials and Method section.

The Range of recovery (%) was in between 98.04 and 99.69 for OMC and in the range of 95.77–97.31for BMDM. The % RSD was in the range of 0.54 and 0.55 for OMC and BMDM respectively. This % RSD values is far less than 1 as shown in Table 5. Thus it is evident that an accurate analytical method is developed for the determination of OMC and BMDM in the sunscreen products [14]. On

Table 4
Linearity of OMC and BMDM analysis.

OMC			BMDM		
Conc (μg/ml)	Absorbance	R^2	Conc (μg/ml)	Absorbance	R^2
1.01	0.096		1.00	0.100	
2.02	0.226		2.00	0.240	
4.05	0.459	0.9997	4.01	0.467	0.9996
6.07	0.685		6.01	0.697	
8.10	0.906		8.02	0.925	
10.12	1.128		10.02	1.146	

Please cite this article as: S. Lavakumar, P. A. Vivekanand and A. A. M. Prince, Simultaneous analysis of octylmethoxycinnamate and butylmethoxydibenzoylmethane in sunscreen products by a validated UV-spectrophotometric method, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2020.07.025

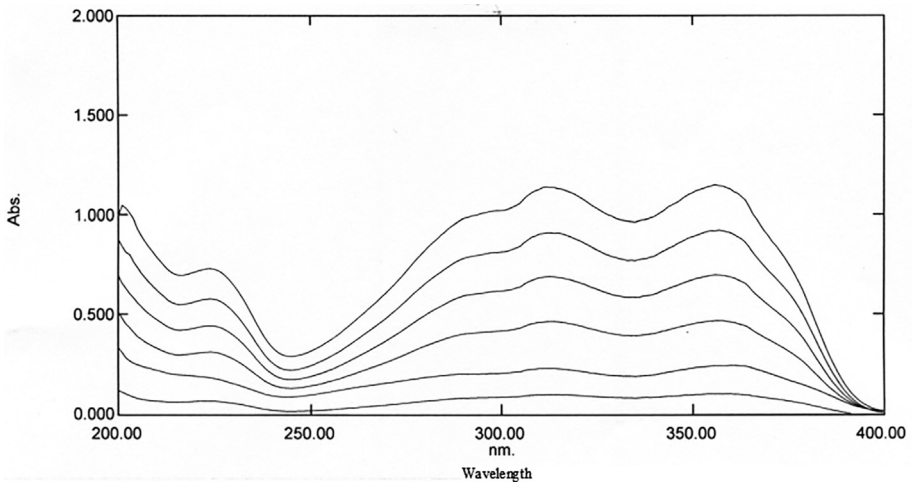


Fig. 1. UV spectrum of calibration standard solution of OMC and BMDM at different concentrations.

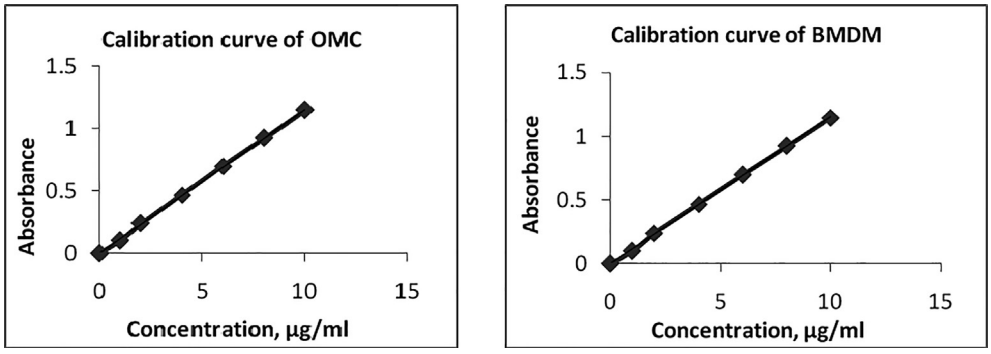


Fig. 2. Calibration curves of OMC and BMDM analysed on UV–Vis spectrophotometer.

Table 5
Accuracy and precision of OMC and BMDM analysis.

OMC					BMDM				
Added amount (µg/ml)	Experimentally determined amount (µg/ml)	Absorbance	Recovery (%)	% RSD	Added amount (µg/ml)	Experimentally determined amount (µg/ml)	Absorbance	Recovery (%)	% RSD
4.205	4.173	0.469	99.23		4.205	4.056	0.467	96.46	
4.235	4.164	0.468	98.32		4.235	4.056	0.467	95.77	
4.216	4.155	0.467	98.55		4.216	4.056	0.467	96.21	
4.230	4.182	0.468	98.86		4.230	4.065	0.468	96.09	
4.212	4.155	0.469	98.65	0.54	4.212	4.073	0.469	96.71	0.55
4.224	4.182	0.469	99.00		4.224	4.073	0.469	96.44	
4.168	4.155	0.467	99.69		4.168	4.056	0.467	97.31	
4.224	4.199	0.473	99.42		4.224	4.108	0.473	97.26	
4.256	4.173	0.471	98.04		4.256	4.091	0.471	96.12	

comparing these data with the reported data for OMC analysis in creams by HPLC with recovery % of 95.6–103.5% and % RDS of 1.0–2.3% [10] as well as analysis after extraction using supercritical fluid with recovery % of 99.55–103.31 [9], one can easily judge the reliability of this method.

7. Repeatability of the system

Both the emulsion systems with OMC and BMDM sunscreens were subjected to six times repeat analysis using the procedure described. The reproducibility (Table 6) was confirmed by the recovery (%) range of 98.40–99.49 for OMC and 97.77–99.76 for

Table 6
Repeatability of the analytical method.

Preparation	% OMC	Recovery ± RSD (%)	% BMDM	Recovery ± RSD (%)
O/W emulsion	1	98.40 ± 0.17	1	99.14 ± 0.31
	2	99.11 ± 0.32	2	99.42 ± 0.43
	4	99.49 ± 0.48	4	99.38 ± 0.36
W/O emulsion	1	97.67 ± 0.48	1	97.77 ± 0.31
	2	98.77 ± 0.39	2	99.05 ± 0.33
	4	98.98 ± 0.29	4	99.76 ± 0.05

Please cite this article as: S. Lavakumar, P. A. Vivekanand and A. A. M. Prince, Simultaneous analysis of octylmethoxycinnamate and butylmethoxydibenzoylmethane in sunscreen products by a validated UV-spectrophotometric method, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2020.07.025

BMDM with % RSD of 0.17–0.48 and 0.05–0.43 for OMC and BMDM respectively.

8. Conclusions

In this study an accurate, rapid, simple and inexpensive method for the determination of OMC and BMDM in sunscreen products has been established using UV spectrophotometer. The method is validated as per ICH guidelines. Optimized solvent system is methanol with UV max 310 nm for OMC and 357 nm for BMDM, linearity range of OMC is 1.01 to 10.12 μg/ml (R^2 = 0.9997) and BMDM is 1.00 to 10.02 μg/ml (R^2 = 0.9996), % recovery of OMC (98.04–99.69) and relative standard deviation (%RSD, 0.54) and % recovery of BMDM (95.77–97.31) and relative standard deviation (% RSD, 0.55), highlights the accuracy of the method developed. The method is compatible to wide variety of products composed of oil in water and water in oil emulsions containing low, intermediate, and high OMC and BMDM levels (1%, 2%, and 4%) gave good recovery percentages. This method is very practical in meeting dynamic need of formulation development and suitable for quality assurance of all types of skincare products containing OMC and BMDM. However, this method is suitable for sunscreen products comprising solely OMC and BMDM as the UV filter, any other chemical species with an absorbance in the range of OMC and BMDM could cause interference and might lead to erroneous results. The future scope lies in expanding the scope of the discussed method for determination of different sun care agents and products containing them. This work certainly increases the applicability of this method in the quality assurance of cosmetic and prescription based sunscreen products.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] E. Gilbert, F. Pirot, V. Bertholle, L. Roussel, F. Falson, K. Padois, Commonly used UV filter toxicity on biological functions: review of last decade studies, Int. J. Cosmet. Sci. 35 (2013) 208–209.
[2] P. Kullavanijaya, H.W. Lim, Photoprotection, J. Am. Acad. Dermatol. 52 (2005) 937–958.
[3] K. Jung, M. Seifert, T.h. Herrling, J. Fuchs, UV-generated free radicals (FR) in skin: their prevention by sunscreens and their induction by self-tanning agents, Spectrochim. Acta A 69 (2008) 1423–1428.
[4] O. Barel, M. Paye, H.I. Maibach, Handbook of Cosmetic Science and Technology, third ed., Informa Healthcare, New York, 2009.
[5] European Directive 76/768/EEC of 27 July 1976.
[6] Department of Health and Human Services, Food and drug administration, Sunscreen drug products for over-the-counter human use; final monograph. Federal Register, 64 (1999) 27666–27693.
[7] J. Cheng, Y.-L. Li, R.L. Roberts, G. Walker, Analysis of 2-ethylhexyl-p methoxycinnamate in sunscreen products by HPLC and Raman spectroscopy, Talanta 44 (1997) 1807–1813.
[8] Y. Shih, F.-C. Cheng, Determination of sunscreen agents in cosmetic products using microwave assisted extraction and liquid chromatography, J. Chromatogr. A. 876 (2000) 243–246.
[9] S.-P. Wang, W.-J. Chen, Determination of *p*-aminobenzoates and cinnamate in cosmetic matrix by supercritical fluid extraction and micellar electrokinetic capillary chromatography, Anal. Chim. Acta. 416 (2000) 157–167.
[10] S. Simeoni, R. Tursilli, A. Bianchi, S. Scalia, Assay of common sunscreen agents in suncare products by high-performance liquid chromatography on a cyanopropyl-bonded silica column, J. Pharm. Biomed. Anal. 28 (2005) 250–255.
[11] S.K. Motwani, S. Chopra, F.J. Ahmad, R.K. Khar, Validated spectrophotometric methods for the estimation of moxifloxacin in bulk and pharmaceutical formulations, Spectrochim. Acta A. 68 (2007) 250–256.
[12] P. Charoennit, N. Lourith, Validated UV-spectrophotometric method for the evaluation of the efficacy of makeup remover, Int. J. Cosmet. Sci. 34 (2012) 190–192.
[13] M. Kanlayavattanakul, N. Kasikawatana, N. Lourith, Analysis of octyl methoxycinnamate in sunscreen products by a validated UV-spectrophotometric method, J. Cosmet. Sci. 67 (2016) 167–173.
[14] The European Agency for the Evaluation of Medicinal Products, ICH Topic Q2B Note for Guideline on Validation of Analytical Procedure: Methodology (The European Agency for the Evaluation of Medicinal Products, London, UK, 1996).
[15] AOAC international, guideline working group, AOAC international guidelines for validation of botanical identification method, J.AOAC.Int, 95 (2012) 268–272.
[16] N. Lourith, M. Kanlayavattanakul, Appraisal of Thai glutinous rice husk for health promotion products, J. Cereal Sci. 57 (2013) 343–347.

Please cite this article as: S. Lavakumar, P. A. Vivekanand and A. A. M. Prince, Simultaneous analysis of octylmethoxycinnamate and butylmethoxydibenzoylmethane in sunscreen products by a validated UV-spectrophotometric method, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2020.07.025