

A comparative analysis of cooked smoked cockerel products derived from male layer-type chickens (Lohmann Brown Classic hybrid) and dual-purpose cocks (based on Bresse Gauloise)

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Abstract. Breeding of chickens is divided in two categories: meat production with focus on the males, and egg production – targeting the females. Culling of male layer-type chickens is a long-standing practice but is now ban some European countries. The dual-purpose cocks (based on Bresse Gauloise) are potential solution to the problem with banned culling practices. The aim of this work is to compare the cooked smoked cockerel products derived from male layer-type chickens (MLC) and dual-purpose cocks (DPC). The highest sensory scores were awarded to the thighs and fillets of the DPC. The hardness, springiness, gumminess, and chewiness, were greater in the thighs of the MLC. In contrast, these parameters were lower in the fillets. The degree of proteolysis in the thighs and fillets of the MLC was greater. The protein content in the thigh was not affected by the breed of the cockerels. In contrast higher protein content in MLC fillets was found. Fat or ash content was not affected significantly by the breed of the cockerels. Overall, both breeds of cockerels used for the production of cooked smoked products had a similar and sufficiently high yield, establishing an opportunity for their industrial utilization.

1 Introduction

The poultry sector is experiencing rapid growth worldwide, with poultry meat being one of the most consumed foods. According to the Food and Agriculture Organization of the United Nations, global poultry production has dramatically increased from 9 million tons in 1961 to 134 million tons in 2020 [1].

Slow-growing chickens, raised free-range or in organic systems, positively impact meat quality [2-3]. However, despite their potential, male layer-type chickens are currently not considered suitable for meat production. Typically, these birds are culled immediately after hatching due to poor performance. This long-standing practice has faced extensive criticism, leading the European Union to ban the culling of male chickens [4]. France and Germany are the first countries to implement this ban, starting in 2022. Consequently, alternative strategies, such as appropriate breeding methods, must be explored to utilize male layer-type chickens for meat production [5]. This shift could potentially create a market gap due to the limited availability of parent lines capable of producing layer-type chickens suitable for alternative rearing systems or floor-raising. Stock lines that, in conjunction with layers, could meet emerging market demands. Petkov et al. [4] reported the importation of French indigenous breed Bresse Gauloise birds to the Institute of Animal Science – Kostinbrod a few years ago. This import aimed to establish a new line, BB, which is currently part of the country's gene pool. The researchers are

focused on developing a dual-purpose crossbreed based on the Bresse Gauloise breed, where females are bred for egg production and males for meat [1, 4-6].

On the other hand, a few studies indicate that male layer-type chickens exhibit superior quality characteristics compared to male broilers, although this claim relies on slaughter age and rearing conditions [7-8]. Additionally, Soisontes [9] reveals that male laying chickens are widely utilized in Thailand for meat production, with only a small proportion being processed into animal feed. Considering the energy resources expended for hatching and the criticisms surrounding culling, it can be concluded that the killing of male layer-type chickens is highly wasteful [4, 10]. Therefore, their utilization through standard meat processing or alternative approaches is necessary.

Various processes, including brine injection, tumbling, steaming, and smoking, are commonly employed in the production of cooked poultry products. Tumbling, involving vigorous meat massage in rotating drums (tumblers), facilitates the penetration, spread, and solubilisation of brine, as well as the extraction and dispersion of salt-soluble proteins on the muscle surface [11-12]. The intensity and duration of massaging, combined with the degree of embrittlement, enhance yield and improve sensory characteristics, such as juiciness [13]. Vacuum massage (tumbling) degrades salt-soluble muscle proteins from the myofibrils and denatures them under heat, resulting in reduced intercellular spaces and strong contraction of denatured myofibrils. This process forms a three-dimensional

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structural network, allowing the retained brine and inherent water to provide density, hardness, and cohesion to the finished product [14]. The characteristic sensory qualities develop during heat treatment and smoking. Under the influence of heat and smoke, a series of reactions occur, enabling the formation of new compounds in the meat components, supporting enhanced overall food absorption, and imparting a distinctive taste and aroma to the cooked smoked meat products [15].

Finally, it is important to note that all the aforementioned statements have a strong correlation with the breed, age, and diet of the cockerels [1, 4-8, 16].

Therefore, the aim of this work is to compare the cooked smoked cockerel products derived from male layer-type chickens (Lohmann Brown Classic hybrid) and dual-purpose cocks (based on Bresse Gauloise).

2 Materials and methods

2.1 Materials

For the purpose of the experiment male layer-type chickens (Lohmann Brown Classic hybrid) - MLC and dual-purpose cockerels (based on Bresse Gauloise) - DPC were used. Both breeds were reared in the experimental poultry farm of the Institute of Animal Science - Kostinbrod, Bulgaria until the age of 9 weeks, described in details by Petkov et al. [3] and Popova et al. [1, 7-8]. Cockerels were slaughtered in a certified poultry abattoir and stored frozen at -18°C for 1 month in polyamide bags.

Salting materials and smoking chips were bought from specialized merchant.

2.2 Experimental design

The brine for injection (10° Bome) was prepared by solvation of 1.2 kg nitric salt (0.55 NaNO₂/kg) and 0.01 kg crystal sugar in 10 litres of water.

Thawed cockerels were injected with 20% brine by their weight (Table 1). Injected cockerels were transferred in vacuum-tumbler machine with another 20% brine by their weight. The applied regime of vacuum-tumble was: 15 min tumble, 5 min rest for a total of 2 hours at 80 kPa and 4°C. The processing of the cockerels continues with steam cooking and smoking in industrial steam boiler (Allroun-System “Rondair”, Rauch and Wärmetechnik GmbH&Co.KG, West Germany). First step is drying with hot air for 60 min at 65°C. Second step was smoking at 65 – 70°C for 120 min and finally boiling with steam at 76 - 78°C until 72°C are reached in the centre of the fillet. The cockerels were cooled by flow of cold air until 10°C in fillets. Cooked smoked cockerels are stored in polyamide bags at 0 - 4°C for 24 hours.

The experiment was done in two separate batches each consisted of 7 cockerels from both breeds or total of 28 as presented in Table 1.

All of the following analyses were conducted after cutting the left thigh and breast fillet, presented as four samples: TMLC – thigh of male layer-type chicken and

TDPC – thigh of dual-purpose cocks, and FMLC – breast fillet of male layer-type chicken and FDPC – breast fillet of dual-purpose cocks.

2.3 Proximate composition

The total amount of nitrogen was determined by the Kjeldahl method, according to AOAC 992.115-1992 [17], and the protein content was calculated using the nitrogen-protein factor of 6.25. The quantity of fat was determined by extraction with diethyl ether using the Soxhlet apparatus [18]. The moisture content was determined by a gravimetric method after drying the samples at 104°C overnight [19]. The quantity of total ash (mineral content) was determined by combustion in a muffle furnace at 400-600°C [20].

Table 1. Experimental design

		DPC	MLC
Batch №1	Initial mass, kg	5.25	5.50
	Average individual mass, kg	0.75	0.78
	Brine for injection (20%), L	1.05	1.10
	Mass after injection, kg	5.90	6.10
	Brine in the tumbler (20%), L	1.18	1.22
	Mass after tumble, kg	6.75	7.00
	Final mass after cooking and smoking, kg	4.90	4.85
	Yield, %	93.33	88.18
Batch №2	Initial mass, kg	6.40	5.85
	Average individual mass, kg	0.71	0.83
	Brine for injection (20%), L	1.28	1.17
	Mass after injection, kg	7.10	6.40
	Brine in the tumbler (20%), L	1.42	1.28
	Mass after tumble, kg	7.70	7.05
	Final mass after cooking and smoking, kg	5.85	5.45
	Yield, %	91.41	93.16
Average Yield		92.37±0.7	90.67±1.1

2.4 Sensory profile

Sensory evaluation of cooked smoked cockerel products was performed using a scale according to the methodology of Stanisławczyk, et al. [21] with minor modifications, with pre-prepared sheets of 5-point evaluation, including the following quality indicators: smell intensity (very negative to typical, pleasant very intense), taste intensity (highly negative, very sour to typical, very pleasant), juiciness (very dry to very juicy),

texture (very firm to very tender) and appearance (uncharacteristic to pleasant). The evaluation was performed by a team of 5 evaluators aged between 22–50 years, with verified sensory sensitivity according to ISO 8586:2023 [22]. For proper evaluation, the samples were cut, coded and presented to the panellists in white containers. The sets of samples for the individual ratters were presented in a specific order that was changed during the second rating session to prevent a possible influence of the previous trial on the subsequent one. Between each test, the panellists take breaks (30 s) and rinse their mouths with mineral water. The evaluation was carried out in an odour-free room, at $20\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$, in accordance with the standard.

2.5 Texture profile analysis (TPA)

Texture profile analysis (TPA) was evaluated by the double compression test. For this purpose, the Texture analyser (Lamy Rheology instruments, TX-700 Texture Analyser) equipped with a 50 kg load cell was used. A flat probe with a diameter of 60 mm was used to compress 70% of the initial height of the sample at compression speed of 1 mm/s with delay between the compressions of 5 s. The samples were left at room temperature prior to analysis. Texture profile was presented by the following parameters: hardness, cohesiveness, springiness, gumminess, chewiness and resilience generated from the force-time graph [23]. The procedure for each sample was repeated 9 times of batch.

2.6 Determination of pH value

For this purpose, a portable pH meter Hanna, HI99163 (Hanna Instruments, USA) equipped with a meat probe (FC099) was used. The pH meter was pre-calibrated with certified buffer solutions of pH 4.04 and 6.86 [24]. Measurements are taken at three different points on the sample.

2.7 Colour characteristic

The colour characteristics were represented by: L^* - colour brightness and the ratio a^*/b^* - red/yellow component of colour [25]. The L^* indicator measures the brightness of the colour, whose values range from 0 (black) to 100 (white). The values of the a^* represent the chromatic scale from green (negative) to red (positive), while those of the b^* represent the chromatic scale from blue (negative) to yellow (positive). Using equation (1), the total colour difference ΔE was calculated.

$$\Delta E = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \quad (1)$$

where ΔL^* , Δa^* and Δb^* are the difference between the same muscle group from the different breed.

2.8 Total lipid extraction and determination of the oxidative stability of lipids

The total lipid content was extracted following the method of Bligh and Dyer [26]. The degree of lipolysis was presented as free fatty acid (FFA) content. First, the extracted fat was titrated according to ISO 660:2020 [27] to determine the acid value (AV). The FFA content was determined using equation 2 described by Kitanovski et al [28].

$$FFA = AV * 0.503, \% \text{ Oleic acid} \quad (2)$$

To determine the quantity of primary products of lipid oxidation was used the methodology of Shantha and Decker [29] as known as peroxide value (POV).

The secondary products of lipid oxidation, expressed by the TBA value were determined by the methodology of Botsoglu et al. [30] with modification by Kolev et al. [31].

For the purpose of POV and TBA value was used a Camspec, M 550 (Camspec Ltd., UK) two-beam UV-VIS spectrophotometer (Camspec Ltd., United Kingdom).

2.9 Extraction of muscle proteins and determination of free amino groups

Extraction was performed using phosphate buffer pH 7.3 following the recommendations of Vassilev et al. [32].

The content of free amino groups was determined using ninhydrin reagent and water-ethanol solution of KIO_3 . The absorbance of was measured against blank at 570 nm using a Camspec, M 550 (Camspec Ltd., UK) two-beam UV-VIS spectrophotometer (Camspec Ltd., United Kingdom) [32].

2.10 Statistical analysis

To carry out the statistical analysis of the results, the method of single-factor variance analysis of variables (ANOVA: Single Factor) was used. In this way, a significant effect of rooster breed was determined for each of the individual muscle groups at a significance level of $p \leq 0.05$ [33].

3 Results and discussion

3.1 Proximate composition

The protein content in the tight (TMLC and TDPC) was not affected ($p \geq 0.05$) by the breed of the cockerels (Fig 1). In contrast the protein content in the fillets (FMLC and FDPC) differs significantly ($p \leq 0.05$). The results for the fillets of the dual-purpose cocks confirm the previously reported [1]. On the other had Popova et al. [1] evaluated significantly lower protein content in the muscles of the tight, but also higher moisture, which could explain those deviations.

Either the fat or ash content were not affected significantly ($p \geq 0.05$) by the breed of the cockerels (Fig. 1). The evaluated higher fat content in the tight (TMLC and TDPC) than in the fillets (FMLC and

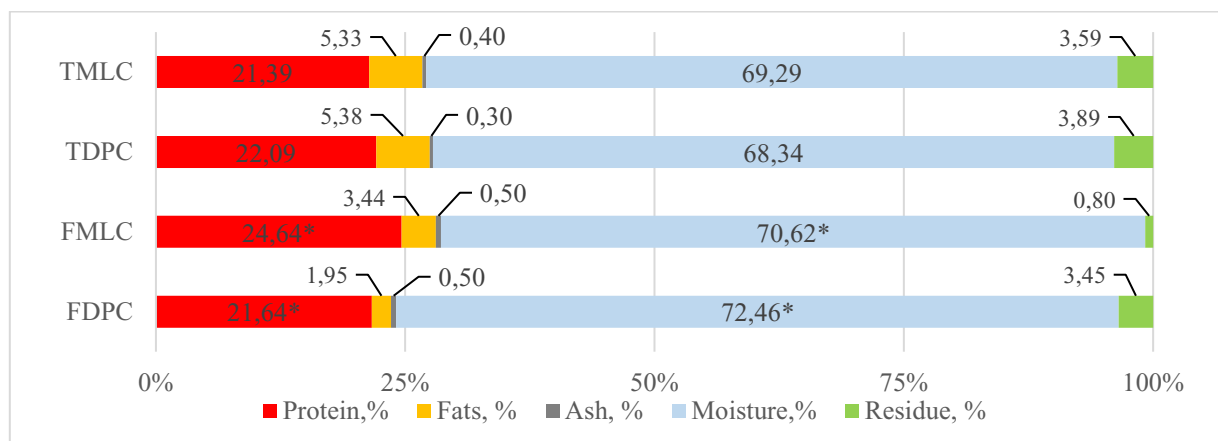


Fig. 1. Proximate composition of the cooked and smoked cockerel product (*indicates a significant $p \leq 0.05$ difference between means for each muscle group separately; Results are presented as Means \pm SEM)

FDPC) confirms previously reported analyses of those muscle groups in the same breeds of cockerels [1, 8].

No matter of the technological processing (injecting and tumbling with brine) moisture content in the final products decreased compared to the raw muscles [1, 8]. This is also confirmed by the evaluated yields (Table 1).

The cooking loss was almost compensated by the injection and tumbling with brine. Therefore, this type of processing is potentially suitable for the production of cooked and smoked cockerels with relatively high yield and low prices.

Sensory profile

The sensory panel did not find any difference or any kind of deviations from normal in the appearance of the cooked smoked cockerels (Fig. 2).

The sensory panel reported a much more juiciness of the FDPC compared to the FMLC which affected their scores. This statement well corresponds with the high moisture content of FDCP (Fig. 1).

The FMLC fillets had the lowest sensory scores explained by their typical/neutral, poorly expressed taste and aroma, and also the lack of juiciness.

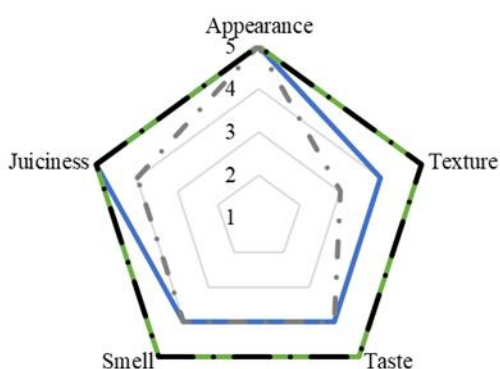


Fig 2. Sensory profile of the cooked and smoked cockerel products

Overall, the tight and fillets of the dual-purpose cocks (TDPC and FDPC) were awarded with the highest sensory scores for all of the evaluated parameters

Texture profile

The evaluated hardness of the TMLC was significantly greater ($p \leq 0.05$) compared to TDPC (Table 2). This confirms the lower sensory scores in texture and juiciness for sample TMLC (Fig. 2).

The hardness, cohesiveness and resilience of the fillets (FMLC and FDPC) were not affected significantly ($p \geq 0.05$) by the breed of the cockerels (Table 2).

Table 2. Texture profile analysis (TPA) of the cooked and smoked cockerel products

Samples/Parameters	TMLC	TDPC	FMLC	FDPC
Hardness, N	154.94* ± 0.64	125.27* ± 0.72	141.62 ± 0.81	145.38 ± 0.61
Cohesiveness, -	0.48 ± 0.03	0.43 ± 0.02	0.44 ± 0.02	0.47 ± 0.03
Springiness, -	0.67* ± 0.02	0.64* ± 0.02	0.60* ± 0.02	0.82* ± 0.03
Gumminess, N	75.94* ± 0.37	53.70* ± 0.45	63.20 ± 0.58	67.64 ± 0.39
Chewiness, N*cm	50.79* ± 0.42	35.16* ± 0.39	38.44* ± 0.48	55.13* ± 0.38
Resilience, -	0.20 ± 0.03	0.18 ± 0.01	0.17 ± 0.02	0.18 ± 0.01

Results are presented as Means \pm SEM. *Indicates a significant ($p \leq 0.05$) difference between means in the same row for each muscle group separately

Texture profile analyse evaluated a correlation between the parameters: springiness, gumminess and chewiness. The greater ($p \leq 0.05$) springiness found in TMLC compared to TDPC potentially led to greater ($p \leq 0.05$) gumminess and chewiness (Table 2). Therefore, the lower springiness, gumminess and chewiness of TDPC would positively affect its juiciness, which confirms the reported by the sensory panel (Fig. 2). In contrast the fillets of the dual-purpose cocks (FDPC) had greater ($p \leq 0.05$) springiness compared to the male layer-type chickens' fillets (FMLC). Similar tendency in chewiness was also found for those samples, but deviations in the gumminess were not significant ($p \geq 0.05$).

Technological properties

The pH value of all examined samples was not affected significantly ($p \geq 0.05$) by the breed of the cockerels (Table 3).

The lightness of the colour (L^*) on the surface of the tight muscles was affected significantly ($p \leq 0.05$) by the breed of the cockerels (Table 3). The TDPC were higher in colour lightness (L^*) making the colour look brighter and paler, which is preferred by the consumers for that type of product. The lightness of both fillets (FMLC and FDPC) was not significantly different ($p \geq 0.05$).

Table 3. Technological properties of the cooked and smoked cockerel products

Samples/ Parameters	TMLC	TDPC	FMLC	FDPC
pH value	6.54 ±0.18	6.46 ±0.14	6.26 ±0.07	6.27 ±0.13
Lightness (L^*)	58.18* ±0.26	59.25* ±0.15	67.87 ±0.31	68.57 ±0.30
Red/ Yellow ratio (a^*/b^*)	1.24 ±0.26	1.30 ±0.22	0.88 ±0.19	0.66 ±0.16
ΔE	1.28		2.08	

Results are presented as Means±SEM. *Indicates a significant ($p \leq 0.05$) difference between means in the same row for each muscle group separately

The red/ yellow ratio (a^*/b^*) is often used for cooked meat products, as it represents if the colour is more pinkish/reddish (high a^*/b^* values) or yellowish/brownish (lower a^*/b^* values) [25]. As expected, the red/ yellow ratio (a^*/b^*) of the colour of tight (TMLC and TDPC) was higher compared to the fillets (FMLC and FDPC) as a consequence of their physiological functions and concentration of myoglobin and haem pigments [34] (Table 3).

Our results conclude that the red/ yellow ratio (a^*/b^*) of the colour throughout all samples was not affected significantly ($p \geq 0.05$) by the breed of the cockerels.

The evaluated total colour difference $\Delta E \leq 2$ was considered not a significant and can only be determined by a trained specialist [35]. The total colour difference was minimal between the thigh samples (TMLC and TDPC – Table 3). According to Tkacz et al. [35] at $2 < \Delta E < 5$, even an inexperienced observer can detect a difference in the colour of the studied samples. The ΔE of the fillets (FMLC and FDPC) was too low and sensory panel did not find any difference in the colour as a part of their appearance (Fig. 2).

Hydrolytically and oxidative changes in lipid and protein fractions

The oxidative stability of the cooked and smoked cockerels was presented by the content of free fatty acids (FFA), primary (POV), and secondary (TBA) products of lipid peroxidation (Table 4).

The content of FFA was relatively low for a cooked smoked poultry product compared to previously reported [36]. The evaluated lipolytic changes were

attributed to the applied thermal treatment, and the breed of the cockerels had no significant effect.

The content of primary products of lipid peroxidation (hydroperoxides), expressed as peroxide value (POV) was < 2.00 meq O_2 / kg fat, which is under the EFSA safety criteria for rancidity [37]. By their nature, hydroperoxides are odourless compounds, but they are closely related to the formation of the taste and aroma of the product. They are highly reactive and responsible for the chain-radical reactions leading to the formation of aldehydes, ketones, hydrocarbons, and alcohols [15]. Most of these newly formed compounds are characterized by unpleasant taste and aroma, and also have cancerogenic and mutagenic properties [38]. This is the reason for their regulation [37].

Table 4. Oxidative stability of the cooked and smoked cockerel products

Samples/ Parameters	TMLC	TDPC	FMLC	FDPC
FFA, % oleic acid	0.43 ±0.04	0.42 ±0.05	0.45 ±0.04	0.51 ±0.05
POV, meq O_2 /kg fat	1.52 ±0.17	1.45 ±0.22	1.63 ±0.18	1.59 ±0.20
TBA value, mg MDA/ kg	1.13 ±0.11	1.01 ±0.14	1.00 ±0.17	0.89 ±0.19

Results are presented as Means±SEM. *Indicates a significant ($p \leq 0.05$) difference between means in the same row for each muscle group separately

The quantification of the accumulated malondialdehyde is an indicator of the oxidation of polyunsaturated fatty acids (PUFA), measured by the 2-thiobarbituric reactive compounds (TBA value) [16]. The TBA values vary but not significantly throughout all samples (Table 4). The content of secondary products of lipid peroxidation were at the threshold limit (1 mg MDA/kg) above which the consumer begins to perceive the smell and taste of rancidity [38], yet the sensory panel did not report such findings (Fig 2).

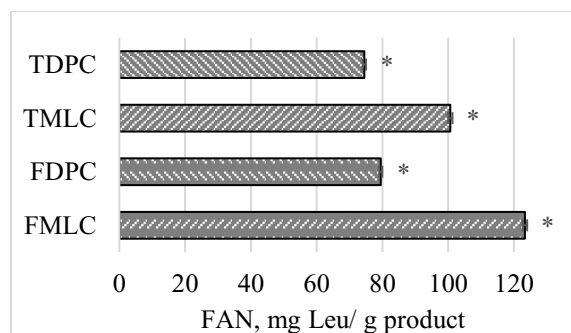


Fig 3. Free amino nitrogen (FAN) of the cooked and smoked cockerel products (*indicates a significant $p \leq 0.05$ difference between means for each muscle group separately; Results are presented as Means ± SEM)

In contrast to hydrological and oxidative changes in lipid fraction, the proteolysis was affected significantly ($p \leq 0.05$) by cooking and smoking process (Fig 3.). The evaluated free amino nitrogen (FAN) content expressing the degree of proteolysis was higher in the male layer-type chickens, both in the thigh TMLC and the fillet

FMLC). Our results confirm the previously stated that the degree of proteolysis is in a close relation protein composition of the muscle which is varies depending on the age, breed and type of diet of the birds [1, 32]. Often the proteolysis is connected with aging of meat, hydroxylation of proteins to peptides and free amino acid, forming the pleasant taste and aroma [32]. In our case the samples (TDPC and FDPC) with lower FAN values (Fig. 3) had a higher sensory score (Fig. 2) *vice versa*.

4 Conclusion

In this experiment, significant differences were evaluated between the compared cooked smoked cockerels' products. Both thighs and fillets of the dual-purpose cocks received higher sensory scores. Parameters of the texture profile, such as hardness, springiness, gumminess, and chewiness, were greater in the thighs of the male layer-type chickens. In contrast, these parameters were lower in the fillets. Only the colour lightness of the thighs was significantly affected by the breed of the cockerels. The lipid fraction was stable, with no significant differences. Due to the thermal processing, the degree of proteolysis both in the thighs and fillets of the male layer-type chickens was greater.

Overall, both breeds of cockerels used for the production of cooked smoked products had a similar and sufficiently high yield, establishing an opportunity for their industrial utilization.

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