

**Research Article****Natural Light Photobioreactor Study of *Nannochloropsis* sp. for Carbon Capture and its Utilization**Aparna Pharande<sup>1\*</sup>, Vasudeo Zambare<sup>2#</sup> and Prashant Kokil<sup>3</sup>**Article Info**<sup>1</sup>Ashwamedh Engineers and Constructions CSL Pvt Ltd, Nashik, Maharashtra, India<sup>2</sup>R&D Department, Balaji Enzyme and Chemical Pvt Ltd, Mumbai, Maharashtra, India<sup>3</sup>Formerly with Environment & Climate Change Department, TATA Power Company Limited, Mumbai, Maharashtra, India**Corresponding author:**

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**Publisher's Note:** IJABR Press stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.**Copyright:** ©2025 by the author(s). Licensee IJABR Press, India. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution- ShareAlike (CC BY -SA) license <https://creativecommons.org/licenses/by-sa/4.0/>**Abstract**

*Nannochloropsis* sp. isolated from Sea water sample and CO<sub>2</sub> capture was studied in modified BG medium with sea water supplementation. A 1.7L photobioreactor with a natural light as a source of light energy with 25 ml/min flow rate of 10, 20 and 40% CO<sub>2</sub> inlet for the period of 8 h per day was used as carbon source in modified Blue green algae (BG) medium for the period of 56h. Parameters studied were CO<sub>2</sub>, O<sub>2</sub> outlet, optical density (OD) and cell count (CFU/ml) after 4 h intervals a day up to 8 h with a gap of 16h night time (without light source & air sparging). Along with some physical parameters like temperature, pH, light intensity and biochemical parameters such as turbidity, dry biomass, bicarbonate and carbonate formations were also monitored. *Nannochloropsis* sp. showed maximum CO<sub>2</sub> capture after 56 h with 20% CO<sub>2</sub> inlet followed by 10% and 40% of CO<sub>2</sub> inlet. Medium pH changed from alkaline pH 8 to acidic pH 6 with a formation of some bicarbonate. Overall, 20% CO<sub>2</sub> inlet photobioreactor (PBR) showed excellent turbidity (171 NTU) indicating *Nannochloropsis* sp. growth and final biomass of 0.738 g/1.7L having highest 78.87% protein content. Thus, the *Nannochloropsis* sp. has potential to utilize the atmospheric CO<sub>2</sub> a global warming gas for its growth and the algal biomass where it can serve a single cell protein for many industrial applications too.

**Keywords:** Microalgae; *Nannochloropsis*; Photobioreactor; Carbon capture.

## Introduction

Global warming and climate change showed an escalating concern which sparked intense research-based technologies for minimizing the levels of atmospheric carbon dioxide (CO<sub>2</sub>) and a most promising and diverse source of photosynthetic microalgae [1]. These microalgae have an exceptional ability to fix the atmospheric CO<sub>2</sub> via photosynthetic route converting it into an organic biomass which can be utilized for various applications [2].

Among the myriad microalgae species, *Nannochloropsis* sp. have emerged as a prime candidate for carbon capture and utilization (CCU) due to their remarkable characteristics [3]. It showed rapid growth rates, temperature and salt tolerance, and a high lipid & protein content, rendering them an attractive feedstock for biofuel and feed applications. Furthermore, *Nannochloropsis* microalgae have been shown to possess a high CO<sub>2</sub> sequestration capacity, making them an ideal species for carbon capture. The utilization of *Nannochloropsis* microalgae for carbon capture offers several advantages over traditional carbon capture and storage (CCS) technologies [4]. Firstly, microalgae-based carbon capture systems can operate at lower costs and with lower energy requirements compared to conventional CCS technologies. Secondly, the biomass generated through microalgae cultivation can be converted into valuable products, such as biofuels, animal feed, and nutritional supplements, thereby offsetting the costs associated with carbon capture. Finally, microalgae can be cultivated on a large scale, making them a potentially significant contributor to global carbon capture efforts.

Despite the promising potential of *Nannochloropsis* microalgae for carbon capture, several challenges need to be addressed to optimize their CO<sub>2</sub> sequestration capacity. These challenges include elucidating the optimal cultivation conditions, such as temperature, pH, and light intensity, to maximize CO<sub>2</sub> capture rates. Additionally, the development of cost-effective harvesting and processing technologies

is essential to ensure the economic viability of microalgae-based carbon capture systems.

Recent studies have investigated the effects of various parameters on the CO<sub>2</sub> sequestration capacity of *Nannochloropsis* microalgae [5-7]. For instance, researchers have examined the impact of CO<sub>2</sub> concentration, light intensity, and temperature on the growth rates and CO<sub>2</sub> sequestration capacities of *Nannochloropsis* microalgae. However, further research is necessary to optimize the cultivation conditions and to scale up the process to commercial levels. This study aims to investigate the effects of various parameters on the CO<sub>2</sub> sequestration capacity of *Nannochloropsis* microalgae and to optimize the cultivation conditions for maximum CO<sub>2</sub> capture rates in a PBR. The results of this study will contribute to the development of a sustainable and cost-effective biological CCU technology, which can help mitigate climate change by reducing atmospheric CO<sub>2</sub> levels.

## Materials and Methods

### Material & Chemical

All chemicals and laboratory media used for this study was procured from HiMedia Laboratories (Mumbai, Maharashtra, India).

### Water sampling and analysis

Sea water sample was collected from Indian side Arabian sea and used for isolation of microalgae and photobioreactor studies.

### Isolation and identification of Sea water microalgae

Sea water microalgae were isolated on BG agar medium and identified microscopically.

### Carbon Capture and Utilization

A small 1.7 L capacity glass tube PBR was designed with an intermittent CO<sub>2</sub> and O<sub>2</sub> gas flow rate of 25ml/min for day time 8h and night time 16h, respectively. A modified BG medium fortified with sea water was used for this study in a PBR with a natural light as a source of energy. An inoculum of *Nannochloropsis* sp. with a count of  $1.2 \times 10^6$  CFU/ml having OD 0.051 at 665 nm and turbidity 30.6 NTU, and dry biomass of 0.082g/L was used for this study. Different

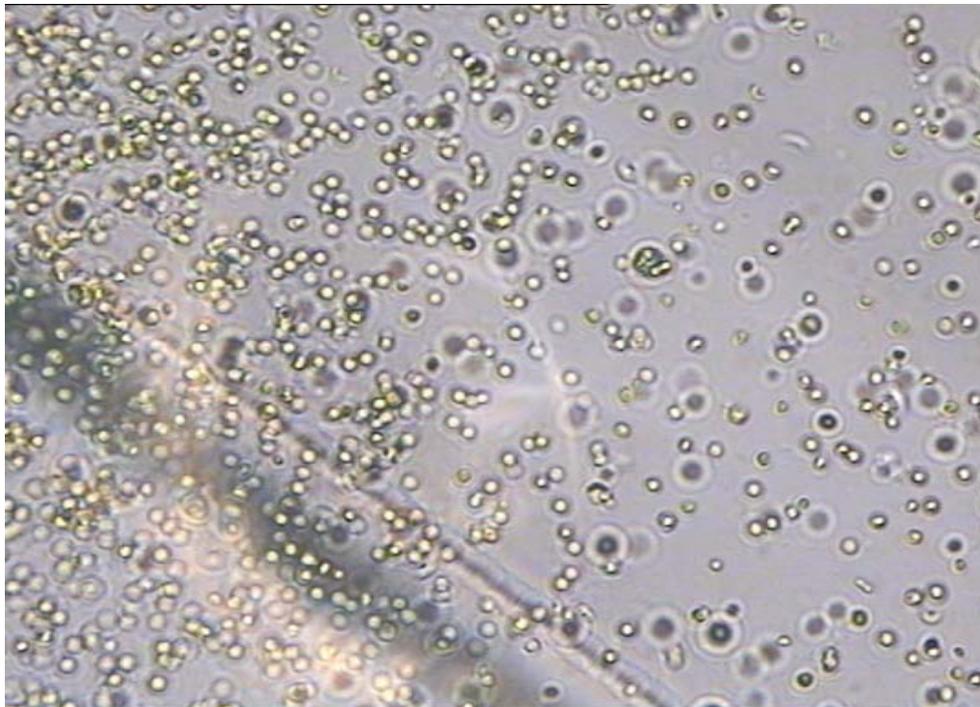
concentrations of CO<sub>2</sub> 10, 20 and 40% as inlet gas for the period of 8 h per day was used as carbon source in modified BG medium for the period of 56h. After inoculation, the physical (CO<sub>2</sub>, O<sub>2</sub> outlet, optical density, turbidity [8], temperature, pH, light intensity) and biochemical parameters (cell count, dry biomass, bicarbonate and carbonate) were monitored after 4 h intervals in a day time up to 8 h only.

### **Biomass Harvesting and Analysis**

The microalgal biomass collected by simple centrifugation method and used for its moisture, protein, carbohydrate, fats and ash content using standard methods [9-10].

### **Results and Discussion**

Sea water microalgae were isolated from the Arabian Sea and was identified as *Nannochloropsis* sp. The microscopic photograph of the identified microalgae is shown in Figure 1. Microscopic observation of *Nannochloropsis* sp. showed small, spherical or slightly ovoid, non-motile, green coloured microalgae with a diameter of 2-6 µm. It has been reported that the *Nannochloropsis* sp. contains nutritionally important chemicals such as polyunsaturated fatty acids (PUFAs), mainly eicosapentaenoic acid (EPA), polyphenols, carotenoids and vitamins which are important for human [11].

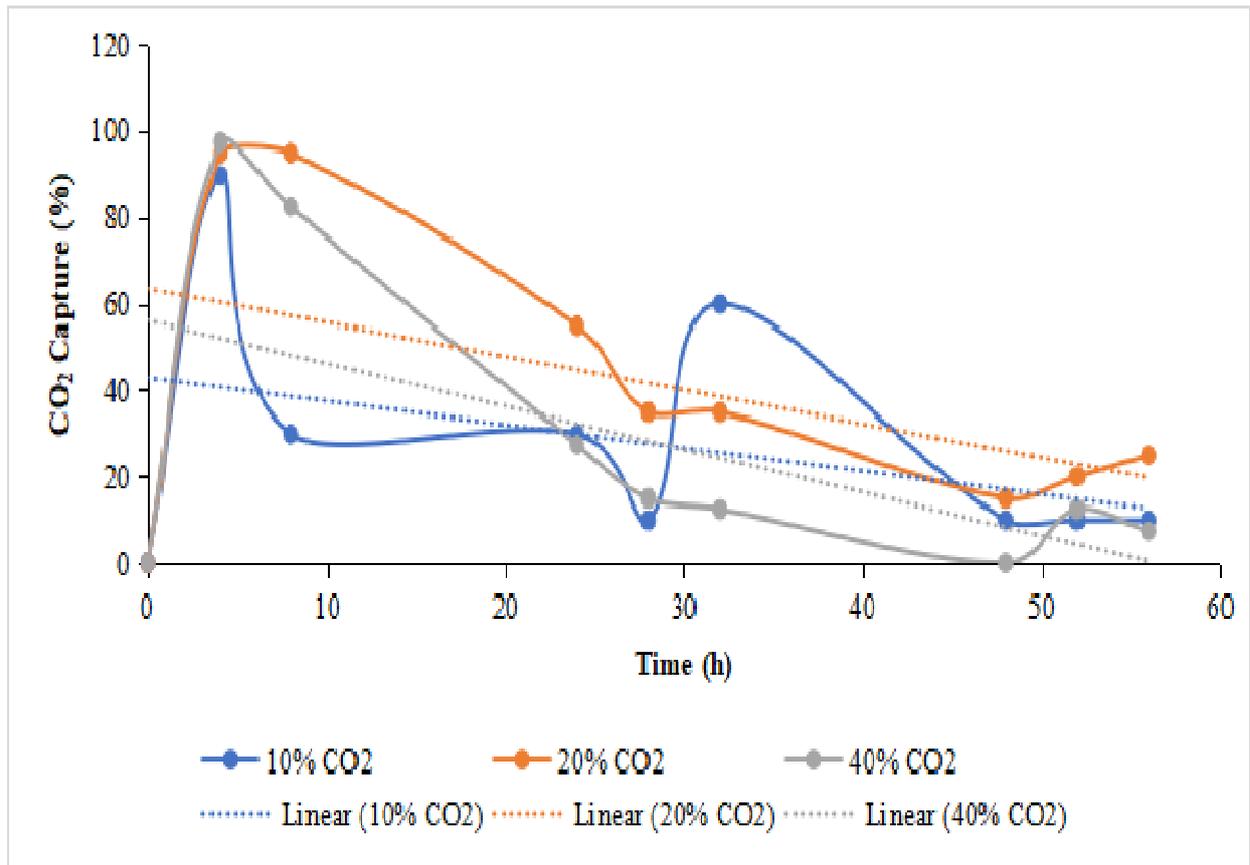


**Figure 1:** Microscopic image of Arabian sea water microalgae *Nannochloropsis* sp.

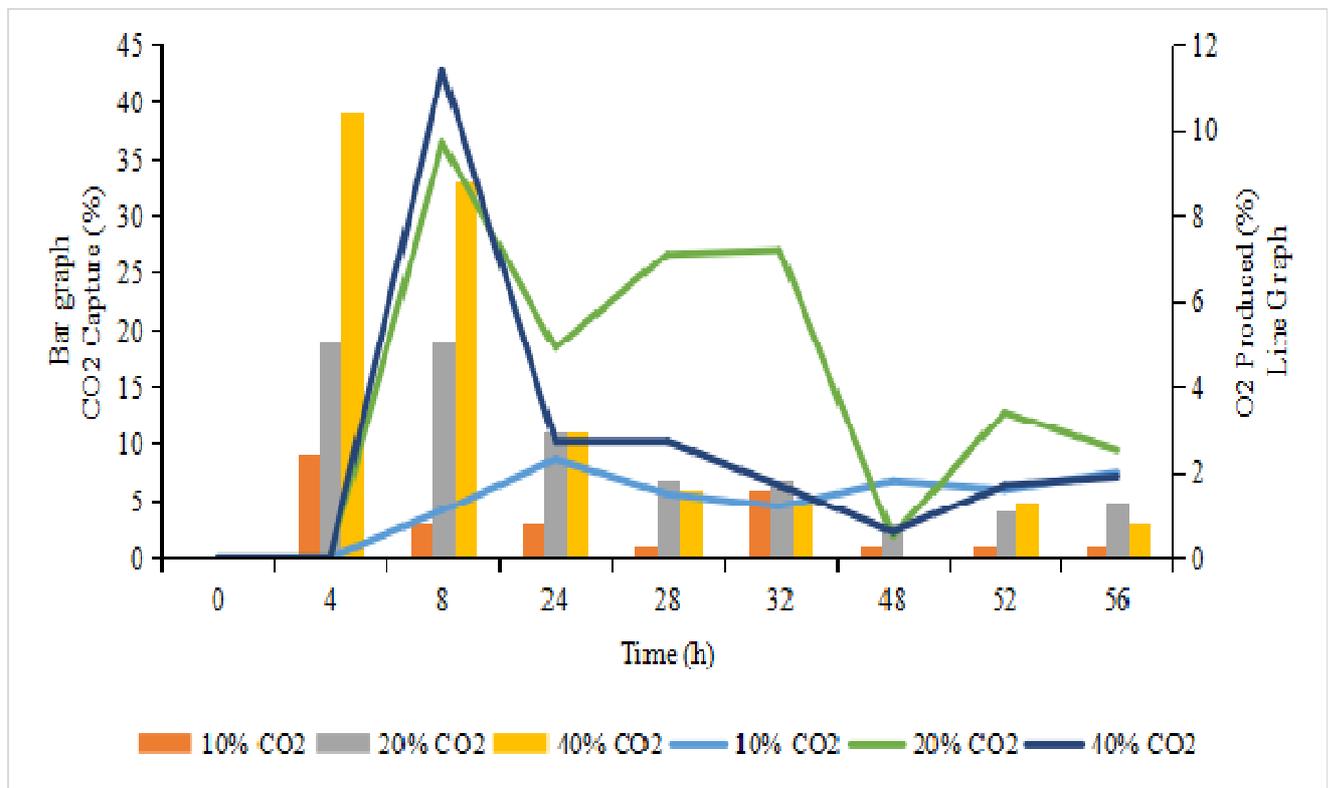
### **Carbon Capture and Utilization**

#### **Carbon Capture**

Effect of different levels of CO<sub>2</sub> for growth and carbon capture by *Nannochloropsis* sp. was observed and it was found that the 20% CO<sub>2</sub> inlet showed maximum 25% carbon capture from the total gas inlet into the PBR followed by 10 and 40%. Figure 2 is showing linear decreasing CO<sub>2</sub> concentration in outlet indicating the CO<sub>2</sub> capture by *Nannochloropsis* sp. Figure 3 showed combination of CO<sub>2</sub> and O<sub>2</sub> outlet measurement where *Nannochloropsis* sp. converting CO<sub>2</sub> to O<sub>2</sub> photosynthetically using light as energy source. Though the levels of oxygen are not correlating with the CO<sub>2</sub> utilization but it showed some indications. This indicate that *Nannochloropsis* sp. can tolerate 40% CO<sub>2</sub> concentration. Strains like *Euglena gracilis*, *Chlorella*, and *Eudorina* species showed tolerance of 45,40 and 20% CO<sub>2</sub> concentration, respectively [12-14].



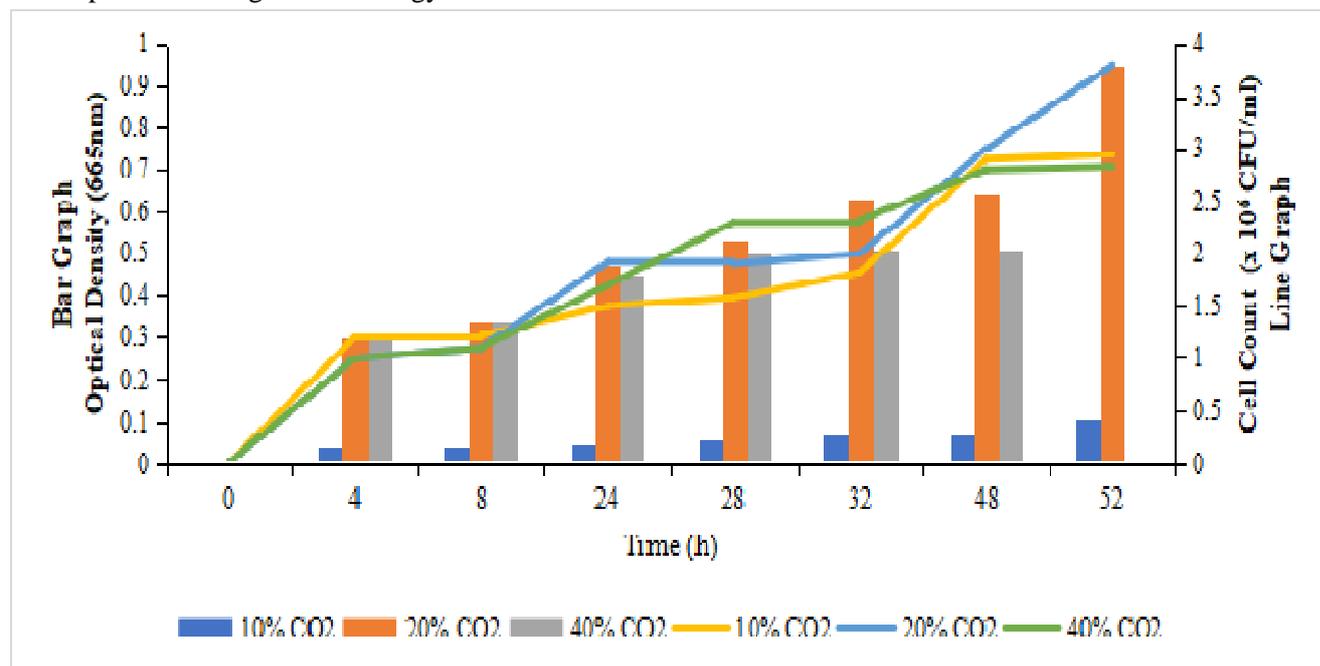
**Figure 2:** Timewise carbon capture trend with different concentrations of CO<sub>2</sub> inlet in PBR.



**Figure 3:** Timewise metabolic profile of carbon capture and oxygen produced

The PBR study analysis was also extended with optical density and cell counting indicating the growth pattern of *Nannochloropsis* sp. optical density showed turbidimetric growth measurement and cell count

showed microbiologically growth measurement. Both measurement parameters showed increasing trend with respect to the time indicating the consumption of CO<sub>2</sub> as carbon source by *Nannochloropsis* sp. with the help of natural light as an energy source.



**Figure 4:** Effect of different carbon concentration on *Nannochloropsis* sp. cell growth in PBR

PBR was also monitored for its physical parameters such as temperature and pH, where no drastic increasing trend in temperature even after the inlet of CO<sub>2</sub> gas inside the PBR but the pH change observed from pH 8 to 6 indicating the metabolic activity of microalgae in PBR. During the sampling interval, the natural light intensity was also monitored and it showed differential light intensities.

**Table 1:** Timewise monitoring of physical parameters in the photobioreactor during CCU by *Nannochloropsis* sp.

Time (h)	CO <sub>2</sub> Inlet								
	10%	20%	40%	10%	20%	40%	10%	20%	40%
	Temperature (°C)			pH			Light Intensity (lux)		
0	28	28	28	8	8	8	8650	3525	3525
4	28	28	28	8	8	8	8650	3525	3525
8	29	27	27	7	6	6	2620	3525	3525
24	25	28	28	7	6	6	9310	13140	13140
28	30	30	30	6	6	6	8550	9150	9150
32	27	27	27	6	6	6	2845	3620	3620
48	25	24	24	7	6	6	8895	11820	11820
52	30	30	30	6	6	6	7830	7240	7240
56	30	27	27	6	6	6	2550	2980	2980

### Carbon Utilization

The microalgal growth and CO<sub>2</sub> capture was also monitored by increasing the turbidity in the PBR. Turbidity is directly proportional to the algal growth which was also checked with dry biomass which

found to be in increasing trend and is also correlating with the turbidity. Again 20% CO<sub>2</sub> inlet showed maximum turbidity and dry biomass production in BPR after 56h. The CO<sub>2</sub> capture and its utilization were also observed by formation of sodium bicarbonate and sodium carbonate and it showed sodium bicarbonate formation but no sodium carbonate. This might be due to the sea water source and carbonation [15]. Hence some sort of carbon is also captured and utilized for sodium bicarbonate formation. The produced sodium bicarbonate has potential use in many chemical and food industry [15].

**Table 2:** Timewise monitoring of biochemical parameters in the photobioreactor during CCU by *Nannochloropsis* sp.

Time (h)	CO <sub>2</sub> Inlet							
	20%	40%	20%	40%	20%	40%	20%	40%
	Turbidity (NTU)		Dry Biomass (g/L)		Bicarbonate (mg/L)		Carbonate (mg/L)	
8	53	53	0.04	0.04	ND	ND	ND	ND
32	90.5	68.5	0.076	0.068	193.2	179.2	0	0
56	171	94.5	0.14	0.068	202	204	0	0

ND- Not determined

At the end of PBR, the cell biomasses were harvested from 20 & 40% CO<sub>2</sub> inlet and showed 0.738g and 0.647g from 1.7L PBR broth, respectively. Overall, biomass also showed highest cell biomass production in 20% CO<sub>2</sub> inlet. Higher level CO<sub>2</sub> inlet may have feedback inhibition effect and hence the cell growth as well as CCU rate is also low.

The compositional analysis of 20% CO<sub>2</sub> inlet showed microalgal biomass with higher (76.87% w/w) protein, 8.93% fats, 2.15% w/w carbohydrates, 5.64% w/w moisture and 6.41% w/w ash. However, the 40% CO<sub>2</sub> inlet showed (64.56% w/w) protein, 11.37% w/w fats, 1.32% w/w carbohydrates, 5.92% w/w moisture and 16.83% w/w ash. Composition wise, the present study results are found to be very contradictory from the results summarized in a research paper by *Nannochloropsis* sp. [16] but the highest protein content showed positive impact on its utilization as a single cell protein.

### Conclusion

Marine microalgae *Nannochloropsis* sp. showed potential carbon capture capacity in sea water with natural light photobioreactor and it could be a potential candidate for further scale up studies and valorisation of microalgae-based products from its biomass.

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**Conflict of interest:** None to declare.

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